※大學學術追求卓越發展延續計畫執行報告格式

Explanation for the Form of the Annual/Midterm/Final Report "Program for Promoting Academic Excellence of Universities（Phase II）"

※ The Annual/Midterm/Final Report contains the following sections:

(Add extra lines or columns if needed.)

I.COVER

Program for Promoting Academic Excellence of Universities（Phase II）

Final Report

下世代光通訊與儲存

Next Generation Optical Communication and Optical Storage Technologies

NSC93-2752-E009-009-PAE
NSC94-2752-E009-009-PAE
NSC95-2752-E009-009-PAE
NSC96-2752-E009-009-PAE

Overall Duration: Month 4 Year 2004 - Month 3 Year 2008
Report Duration: Month 4 Year 2004 - Month 3 Year 2008

National Chiao Tung University
Date:2007/01/15

II. (Form 1) Basic Information of this Sub-Project

<table>
<tr><td colspan="6">Project Title: Next Generation Optical Communication and Optical Storage Technologies</td></tr>
<tr><td colspan="3">Serial No.: NSC96-2752-E009-009-PAE</td><td colspan="2">Affiliation</td><td>National Chiao Tung University
國立交通大學</td></tr>
<tr><td rowspan="4">Principal Investigator</td><td>Name</td><td>Yin- Chieh Lai</td><td rowspan="4">Project Coordinator</td><td>Name</td><td>Grace Tsui
崔怡芬</td></tr>
<tr><td>Tel:</td><td>03-5712121-31746</td><td>Tel:</td><td>(03)5712121-56333</td></tr>
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</table>

	Expenditures[1] (in NT$1,000)		Manpower[2]: Full time/Part time(Person-Months)	
	Projected	Actual	Projected	Actual
FY2004	10,224	10,224	30	30
FY2005	11,231	11,231	30	30
FY2006	10,352.3	10,352.3	30	30
FY2007	10,756.5	10,756.5	30	28.5
Overall	42,563.8	42,563.8	120	118.5

Notes: [1,2] Please explain large differences between projected and actual figures.

Principal Investigator's Signature:

II. (Form 2) List of Works, Expenditures, Manpower, and Matching Supports from the Participating Institutes - SP-II

Serial No.: NSC96-2752-E-009-009-PAE	Program Title: Next Generation Optical Communication and Optical Storage Technologies 下世代光通訊與儲存技術										
Research Item (Include sub projects)	Major tasks and objectives	Expenditures (in NT$1,000)					Manpower (person-month)					Matching Supports from the Participating Institutes (in English & Chinese)
		Salary	Seminar/ Conference-related expenses	Project-related expenses	Cost for Hardware & Software	Total	Principal Investigators	Consultants	Research/ Teaching Personnel	Supporting Staff	Total	
Optical Communca-tion	Develop Optical Communi-cation Technolog-ies	7,600	1,655	6,628.5	10,000	25,883.5	16	0	0	52	68	
Optical Storage	Develop Optical Storage Technolog-ies	7,601.5	825	6,618.5	0.0	15,045	12	0	0	38.5	50.5	
SUM (不含管理費)		15,201.5	2,480	13,247	10,000	40,928.5	28	0	0	90.5	118.5	

IV. (FORM 3) STATISTICS ON RESEARCH OUTCOME OF THIS PROGRAM-II

LISTING		TOTAL	DOMESTIC	INTERNATIONAL	SIGNIFICANT[1]	CITATIONS[2]	TECHNOLOGY TRANSFER
PUBLISHED ARTICLES	JOURNALS	160	-	160	82		
	CONFERENCES	99	-	99	-		
	TECHNOLOGY REPORTS	0	0	0	-		
PATENTS	PENDING	2	1	1	-		
	GRANTED	36	20	16	-		
COPYRIGHTED INVENTIONS	ITEM						
WORKSHOPS/CONFERENCES[3]	ITEM						
	PARTICIPANTS						
TRAINING COURSES（WORKSHOPS/CONFERENCES）	HOURS						
	PARTICIPANTS						
PERSONAL ACHIEVEMENTS	HONORS/ AWARDS[4]	1	1	0			
	KEYNOTES GIVEN BY PIS						
	EDITOR FOR JOURNALS						
TECHNOLOGY TRANSFERS	ITEM						
	LICENSING FEE						
	ROYALTY						
INDUSTRY STANDARDS[5]	ITEM						
TECHNOLOGICAL SERVICES[6]	ITEM				-	-	-
	SERVICE FEE				-	-	-

[1] Indicate the number of items that are significant. The criterion for "significant" is defined by the PIs of the program. For example, it may refer to Top journals (i.e., those with impact factors in the upper 15%) in the area of research, or conferences that are very selective in accepting submitted papers (i.e., at an acceptance rate no greater than 30%). Please specify the criteria in Appendix IV.
[2] Indicate the number of citations. The criterion for "citations" refers to citations by other research teams, i.e., exclude self-citations.
[3] Refers to the workshop and conferences hosted by the program.
[4] Includes Laureate of Nobel Prize, Member of Academia Sinica or equivalent, fellow of major international academic societies, etc.
[5] Refers to industry standards approved by national or international standardization parties that are proposed by PIs of the program.
[6] Refers to research outcomes used to provide technological services, including research and educational programs, to other ministries of the government or professional societies.

V. (FORM4) EXECUTIVE SUMMARY ON RESEARCH OUTCOMES OF THIS PROGRAM

(PLEASE STATE THE FOLLOWING CONCISELY AND CLEARLY)

1. GENERAL DESCRIPTION OF THE PROJECT: INCLUDING OBJECTIVES OF THE PROJECT

(MAXIMUM 3 PAGES)

Subproject 2:

This sub-subject is focused on two important applications of photonic technologies: optical communication and optical storage. The project descriptions and research objectives are given below.

A. Next generation optical communication technologies

The aims of this part of researches are to develop new optical transmission and photonic signal processing techniques and the required device, module, and networking technologies which may play the key roles in next generation optical communication systems. The conducted researches are mainly along the following four directions: (1) Novel Optical Transmission & Processing; (2) Novel Optical Network Architectures & Technologies; (3) Novel Fiber Devices and Laser Sources; (4) Novel Theories & Applications. The research scopes and objectives for each research direction can be briefly summarized below:

(1) Novel Optical Transmission & Processing: (Main investigators: J. Chen, S. Chi)

High efficiency optical transmission through the use of new modulation formats is expected to become more and more important in future optical communication systems. In the past years we have focused on the efficient generation and high-performance transmission of new modulation formats including duo-binary, DPSK, DQPSK, and multilevel ASK signals. The established fiber circulating loop testbed is utilized to experimentally verify the developed idea and techniques. We have also developed a novel bidirectional fiber transmission scheme based on a four-port DWDM wavelength interleaver. By rerouting bidirectional transmission to unidirectional amplification, backscattering noises in the fiber amplifiers are blocked and high optical signal-to-noise-ratio is achieved. For next generation “intelligent” optical networks, optical layer needs to provide the much needed new functionalities with lower cost, smaller power consumption, or less occupied space. New photonic signal processing techniques are thus needed to be developed for implementing this ambitious vision. We have developed optical 2R schemes based on the self-seeded Fabry-Perot laser diodes and tunable optical delay modules based on VCSEL slow light devices.

(2) Novel Optical Network Architectures & Technologies: (Main investigators: J. Chen, S. Chi)

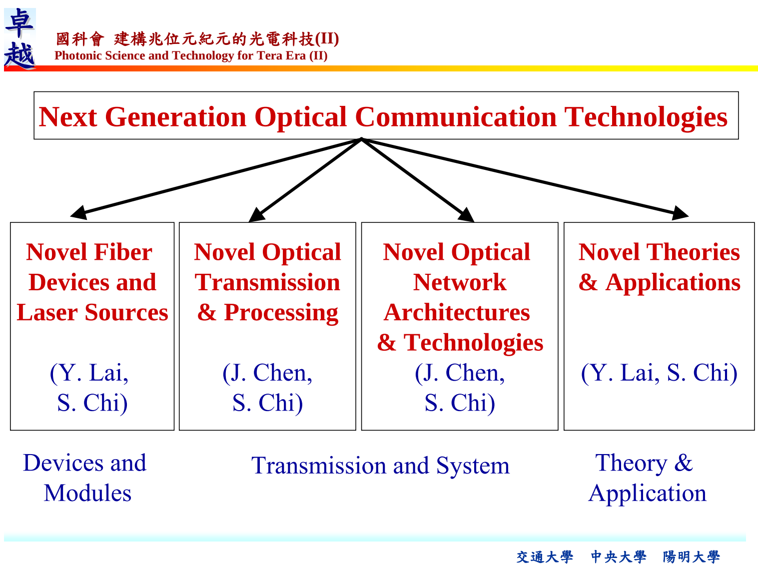
We have developed novel light sources and architectures for optical code-division multiple-access (OCDMA) and Radio-Over-Fiber (ROF) networks, and have also developed several reliable architectures for various optical access systems (i.e., PON). New hybrid fiber/wireless access transmission and networking architectures have also been proposed and demonstrated. In particular, we have developed efficient methods capable of generating Radio-Over-Fiber (ROF) signals by frequency doubling/quadrupling techniques. This result is of great practical importance since it allows one to generate modulated ROF signals at 60GHz or higher with the present EO modulator technology.

(3) Novel Fiber Devices and Laser Sources: (Main investigators: Y. Lai, S. Chi)

We have developed advanced design and fabrication techniques for novel all-fiber devices including fiber gratings and side-polished/fusion-tapered fiber devices. These all-fiber devices have been utilized to build new types of fiber amplifiers and fiber lasers (CW and modelocked). In particular, we have achieved many excellent results on short-wavelength-pass fiber filters, S-band amplifiers, S-band CW lasers, and modelocked fiber soliton lasers.

(4) Novel Theories & Applications: (Main investigators: Y. Lai, S. Chi)

We have investigated the advanced optical soliton effects (on both the classical and quantum levels) for exploring new possible applications. In particular, we have pioneered the theoretical development of entangled quantum solitons, which may find applications in the researches of quantum optics and quantum information.



B. Next generation optical storage technologies:

The recording density of current optical data storage systems has been increasing rapidly but will soon reach the fundamental limitation under the existing framework of far-field optics. Near-field optical system (NFOS) is regarded as the most potential candidate for achieving ultrahigh recording density by breaking through the far-field diffraction limit. However, the application of its super resolution is restricted by many characteristics such as low optical transmission efficiency, fragile mechanical structure, and complex servo control. Our research objectives on this subject are to provide a complete near-field solution by developing the required technologies. The emphases are on creating possibly smallest-spot-size apertures with adequate power throughput, on developing the accurate near-field servo control, and on developing the required Micro-Electric-Mechanical-System (MEMS) fabrication techniques that are needed for implementing the scheme. Generally speaking, the studies can be divided into the following three categories: nano-optics, micro-fabrication and servo-control.

(1) Nano-Optics: (Main investigators: C.-H. Tien)

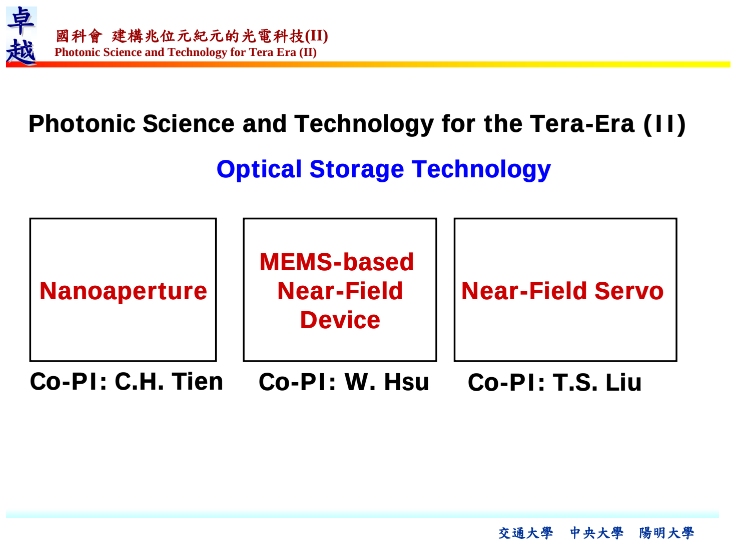
High spatial resolution beyond the diffraction limit can be realized in the optical near-field of a nano-sized metallic aperture, which has drawn much attention for developing new optical storage systems. In order to keep adequate throughput with a sub-wavelength spot, re-forming aperture shapes has been utilized to allow a higher power throughput without expanding the spot size. Aperture shapes like single-ridged (C-shaped), double-ridged (H-shaped), bow-tie shaped, or single silt have all been investigated. The proposed structures have one thing in common: the basic structure is a ridge, or say, a slit. By the waveguide theory, the ridge width of the aperture is an essential parameter for determining the cut-off wavelength of the fundamental propagating mode inside the aperture. When the size of the aperture continuously shrinks, the propagation mode no longer exists. When the dimension is much smaller than the incident wavelength, the depth of the ridge now plays a dominant role in the enhancement mechanism through surface plasmon polariton (SPP) effects. In our studies, numerical analyses based on 3D FDTD (finite difference in time domain) method have been carried out to compare the power throughput and the field spot of two different configurations: single slit and C-aperture, respectively. Furthermore, we have also proposed a brand new structure of apertures which can have the advantages for both the slit and C-aperture. The composite structure has shown higher power throughput and smaller spot size when compared with the C-shaped and slit- aperture respectively.

(2) Micro-fabrication: (Main investigators: W. Hsu)

The combination of the solid immersion lens (SIL) and the nano aperture can provide high power throughput and ultra-high resolution. However, the misalignment between SIL and nano aperture is a critical issue for practically fabricating the near-field pickup head. To overcome these problems we have developed a novel self-alignment process based on the backside exposure technique and the surface tension self-modulation technique during thermal re-flow to effectively reduce the misalignment problem by the MEMS process. We have also continued to develop the required micro-fabrication techniques for practically implementing the near-field pickup head.

(3) Servo-control: (Main investigators: T.S. Liu)

For near-field recording, the distance between the slider and optical disk surface, i.e. the flying height must maintain stable. As a flying height actuator, a piezoelectric bender is used to implement the flying height control in near-field optical disk drives. Firstly, in this study we design a flying pickup head including a piezoelectric bender to complement VCM for controlling both the focusing and track-seeking/track-following motion simultaneously. The pickup head structure differs from traditional CD-ROM and DVD-ROM pickup heads. Secondly, the pickup head is very close to an optical disk which surface contains numerous grooves. Thus the dynamics between the optical disk and the pickup head must be investigated. Different from the conventional laser Doppler interferometers, an optical lever method using two quadrant photodetectors has been developed to measure the flying height variation of a pickup head above a rotating disk. Finally, the adaptive inverse control and PID control are used to implement the focusing and track-following respectively. Coupling between the focusing and track-following is incorporated in the derivation and computer simulation.



2. Breakthroughs and Major Achievements

Subproject 2:

The breakthroughs and major achievements of this sub-project within the four years can be highlighted as follows. More details can be found in the research outcomes section.

A. Next generation optical communication technologies

I. Novel Optical Transmission & Processing :

The established fiber-circulating-loop testbed is the best in Taiwan. We have developed several efficient schemes for generating different modulation formats (duobinary, DPSK, DQPSK, multi-level ASK, etc). These schemes can provide economic solutions for utilizing these modulation formats in practical applications. The developed bidirectional fiber transmission system based on the four-port DWDM wavelength interleaver has superior performance advantages compared to conventional approaches. The developed tunable slow light devices based on quantum dot VCSELs have achieved the largest bitrate-delay product within the similar devices. Such devices have the potential to be used as the building blocks for tunable optical buffers, even though the achievable time delay is still limited and thus practical system applications still call for more investigation. This is also a good example that demonstrates our internal cooperation between different subprojects.

II. Novel Optical Networking Architectures & Technologies :

The proposed and investigated optical access networking architectures should offer many new possibilities for designing future optical accessing networking architectures. In particular, the investigated hybrid wireless/fiber optical access transmission and networking techniques should have great potentials for practical applications. The developed new scheme for generating ROF signals by the doubling/quadrupling techniques is of particular importance**,** since it enables to generate practical ROF modulation signals at 60GHz or higher by the present EO modulator technology.

III. Novel Fiber Devices and Laser Sources :

The established advanced fiber grating fabrication platform is the best in Taiwan and compatible worldwide. The developed short-wavelength-pass fiber filter, S-band amplifiers, and S-band lasers employ unique approaches and have excellent performance. The developed modelocked fiber soliton lasers also employ unique approaches and have exhibited many interesting new soliton phenomena.

IV. Novel Theories & Applications :

The pioneered quantum entangled soliton theory is unique and of great academic importance. It is for the first time that the solitons after nonlinear interaction are rigorously proved to be quantum mechanically entangled. This should open new ways for generating quantum entangled light states.

B. Next generation optical storage technologies

We have used a C-aperture to successfully demonstrate the existence of a propagation mode, which leads to the transmission enhanced by 3 orders of magnitude higher than a square aperture at a similar spot size in the near field. In addition, we have also applied the surface corrugations surrounding the C-aperture on both incident and exit interfaces, which can generate the surface plasmon (SP) waves coupling to the propagation mode. The hybrid effects of the local surface plasmon and waveguide resonance function as a focusing grating. Compared to a 60-nm square aperture, the double-corrugated C-aperture can enhance power throughput by 5 orders of magnitude and reduce the spot area by 30%.

A self-alignment process for the integration of nano aperture and SIL/SSIL is developed. We are the first group to propose a reliable batch process to integrate these two components. Two types of nano-aperture, circular and C shapes, are fabricated and integrated with SIL here. Devices fabricated by the proposed process successfully verify the enhancement effect on the power throughput from 1.68X (circular nano aperture/SIL) to the order of ~103 (C-shape nano aperture/SIL), comparing to the throughput with circular aperture alone. These results demonstrated that the proposed batch process can integrate SIL not only with circular nano apertures, but also nano apertures with different shapes for further enhancement on the near-field system.

Using the direct Monte Carlo simulation method, the pressure distribution of air bearings in near-field optical disks is obtained. The piezoelectric tubes have been proposed to be used in a pickup head for fine tuning the focusing and track-seeking motion. In addition to advanced control method developed in this study to maintain stable and constant flying height, an optical lever method is applied to the flying head experiments by using only photo detectors. The results are validated by comparing with those from laser Doppler interferometers.

By integrating all the above development, we have successfully demonstrated a novel fiber-based near-field optical head consisting of a straw-shaped writing probe and a flat gap sensing probe. The strawshaped probe with a C-aperture on the end face exhibits enhanced transmission by a factor of 3 orders of magnitude over a conventional fiber probe. By the self-injection technique, the high sensitivity of the laser output power to the change in the gap width is used as a feedback control signal to control the disk height. The dual-probe system has been installed on a conventional biaxial actuator to demonstrate the capability of flying over a disk surface with nanometer position precision.

3. Categorized Summary of Research Outcomes. In each research area, please give a brief summary of the research outcomes associated with the area. Note that the summaries should be consistent with the statistics given in Form 3. Please list and number of each research outcomes in order in Appendix II, and list all the publications in top conferences and journals in Appendix III.

Subproject 2:

A. Next generation optical communication technologies

Research highlights of our most important achievements on optical communication researches can be summarized below with the reference to the representative publication list given in the beginning of Appendix II. Our full list of publications can also be found in the later part of Appendix II.

[Research Highlights]

I. Novel Optical Transmission & Processing :

(a) Bi-directional fiber transmission and novel interleaver applications [1-5]

(b) Novel all-optical signal processing (slow lights, Optical 2R, PLC ROADM ….) [6-12]

(c) Cost-effective/high-performance duobinary/DPSK/…. Transmission [13-19]

II. Novel Optical Networking Architectures & Technologies :

(a) Hybrid wireless/fiber access networking [20-24]

(b) Optical access networking (PON, OCDMA, …) [25-28]

III. Novel Fiber Devices and Laser Sources :

(a) Complicated fiber Bragg grating devices: advanced design and fabrication. [29-32]

(b) Novel tapered fiber devices, fiber amplifiers and fiber lasers. [33-40]

(c) High repetition rate modelocked fiber soliton lasers [41-43]

IV. Novel Theories & Applications :

(a) Quantum squeezing and quantum entanglement of optical solitons [44-47]

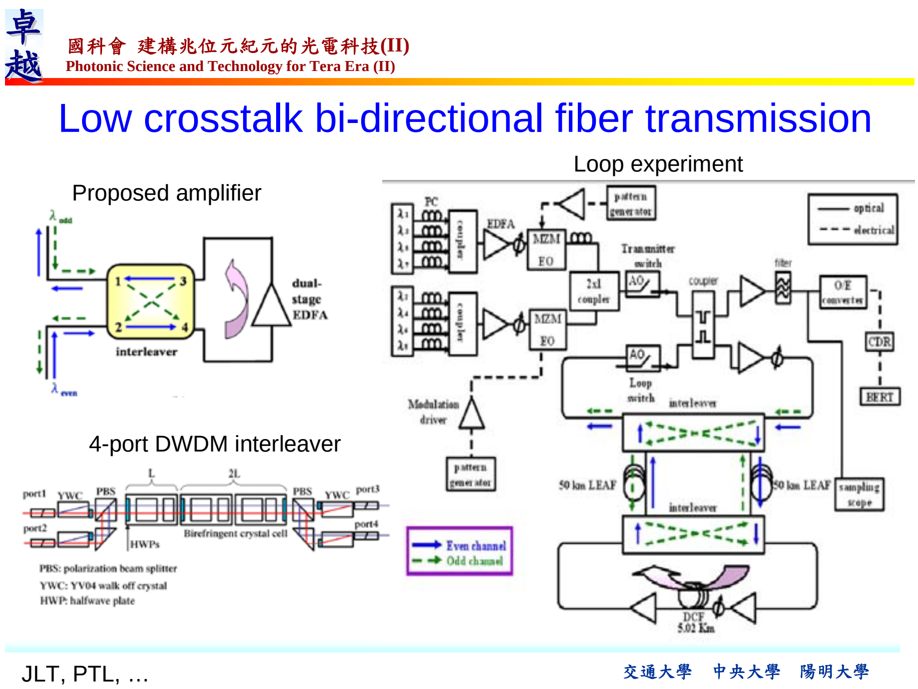
(The reference numbers above and below are refered to the representative publication list given in the beginning of Appendix II.)

Some explanations of these achievements are given below:

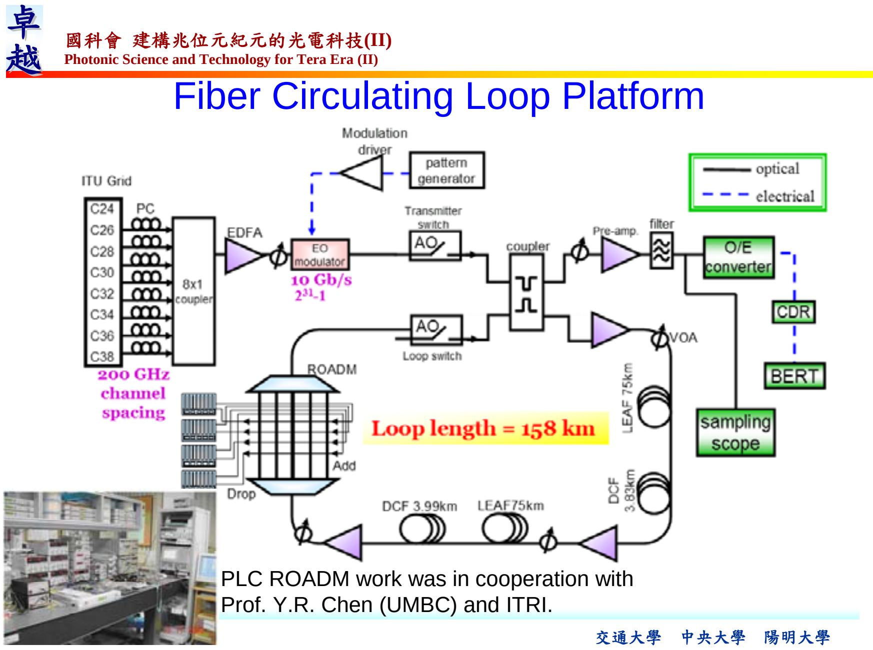
I. Novel Optical Transmission & Processing :

In terms of research infrastructure, we have established the best fiber-circulating-loop testbed in Taiwan and have performed many researches based on this platform [see the lab photos below]. One good example is our study on the bidirectional fiber transmission [1-3]. After 500km transmission, the receiving sensitivity penalty is only

1.5 dB, comparable to conventional single direction transmission performance. In this study a novel 4-port DWDM wavelength interleaver is used to reroute bidirectional transmission into unidirectional amplification, so that the backscattering noises in the fiber amplifiers are blocked and high optical signal-to-noise-ratio (low cross-talk) is achieved.

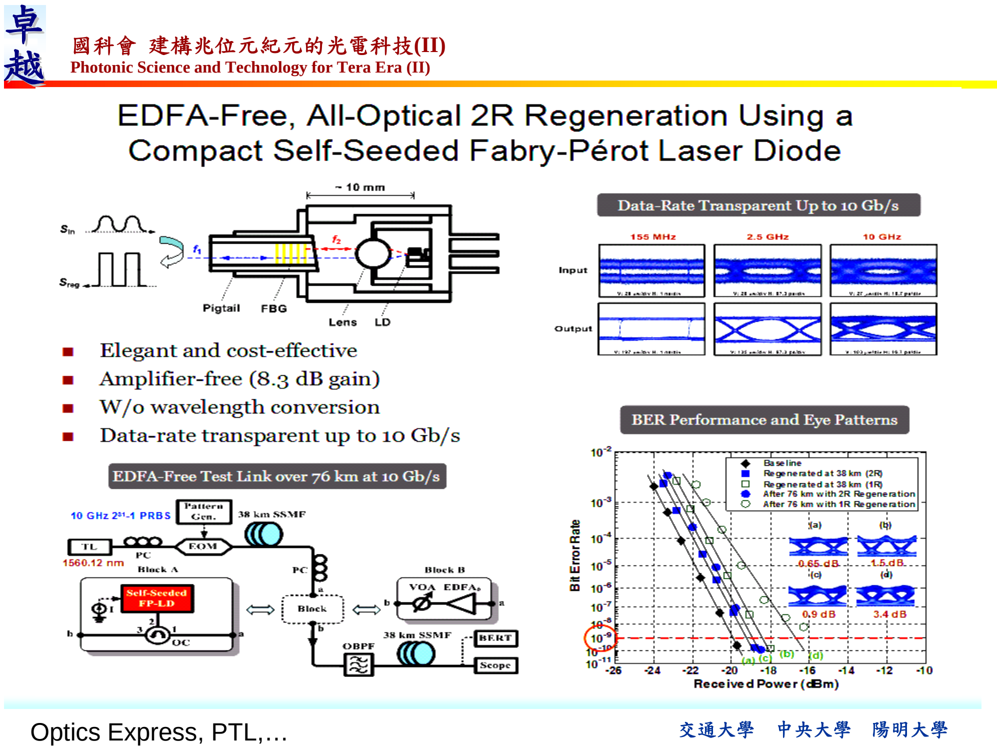


Other good examples are the studies on the DWDM interleaver applications [4-5] and on the Planar-Lightwave-Circuit (PLC) Reconfigurable-Optical-Add-Drop Multiplexer (ROADM) [12]. We have studied the cascading transmission performance of a PLC reconfigurable OADM module in a fiber circulating loop. After 1100 km transmission, the power penalty for all channels < 2.25 dB and less than 2 dB sensitivity variations in cascaded transmission traffic is observed. The accumulated chromatic dispersion becomes obvious when the wavelength is detuned ±11 GHz. This technology can accommodate 32 channels simultaneously. The work was cooperated with Prof. Y.J. (Ray) Chen of UMBC in USA and with ITRI in Taiwan. This is a good example of our external research cooperation.

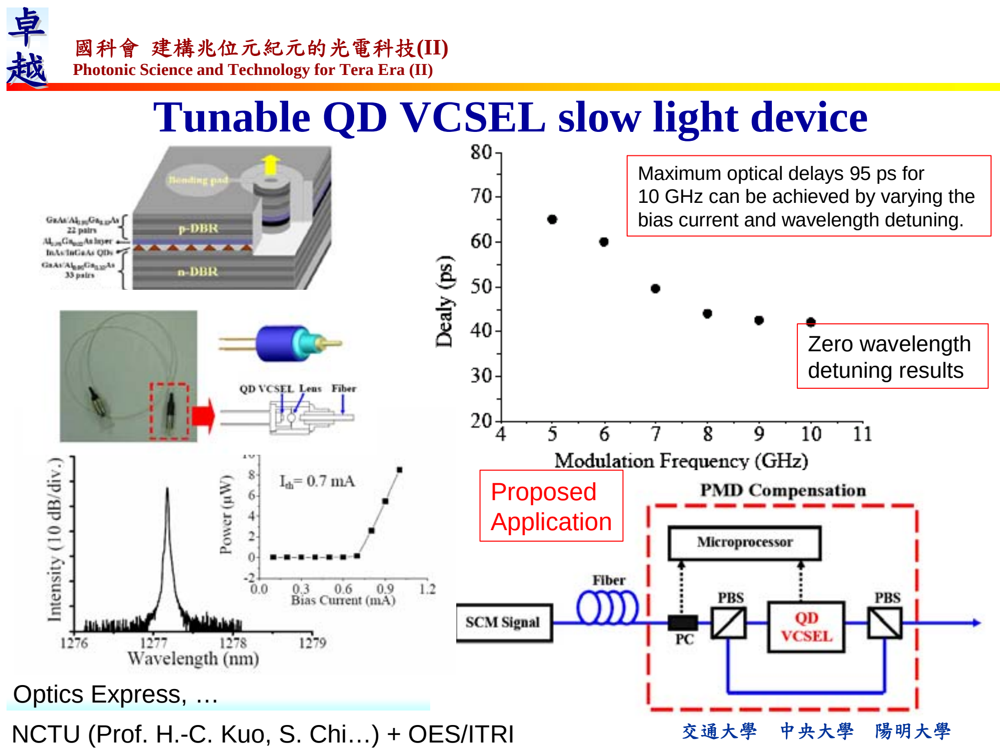


For optical transmission, we have developed several efficient schemes for generating different modulation formats (duobinary, DPSK, DQPSK, baseband digital/radio, etc) by using only a single EO modulator. [16,18-19] These schemes can provide economic solutions for utilizing these modulation formats in practical applications. We have also obtained good theoretical results on the convergence of phase noises in DPSK transmission systems by using novel phase noise averagers [15,17]. This new technique is expected to greatly improve the DPSK receiver performance.

For optical signal processing, we have studied an EDFA-free all-optical 2R regeneration scheme based on a compact self-seeded Fabry-Pérot laser diode (SSFP-LD) [7-9] [See the following figure for the setup]. The proposed 2R regenerator achieves a straight line transmission at 10 Gb/s over 76 km without either the EDFA or the external probe laser, both of which are traditionally required. The proposed compact 2R device has data-rate transparency up to 10 Gb/s and wavelength preserving operation (without wavelength conversion). In addition, we observed eye diagrams of the signal: (a) 2R-regenerated at 38 km; (b) 1R-regenerated at 38 km; (c) after 76 km propagation with 2R regeneration; and (d) after 76 km propagation with 1R regeneration. By using the proposed method, the power penalties, compared with the back-to-back case, were 0.65 and 0.9 dB after transmission over 38 km and 76 km, respectively, at BER = 10^{-9}. However, the 1R-only transmission has larger power penalties of 1.5 and 3.4 dB after transmitting over 38 km and 76 km, respectively, at BER = 10^{-9}.

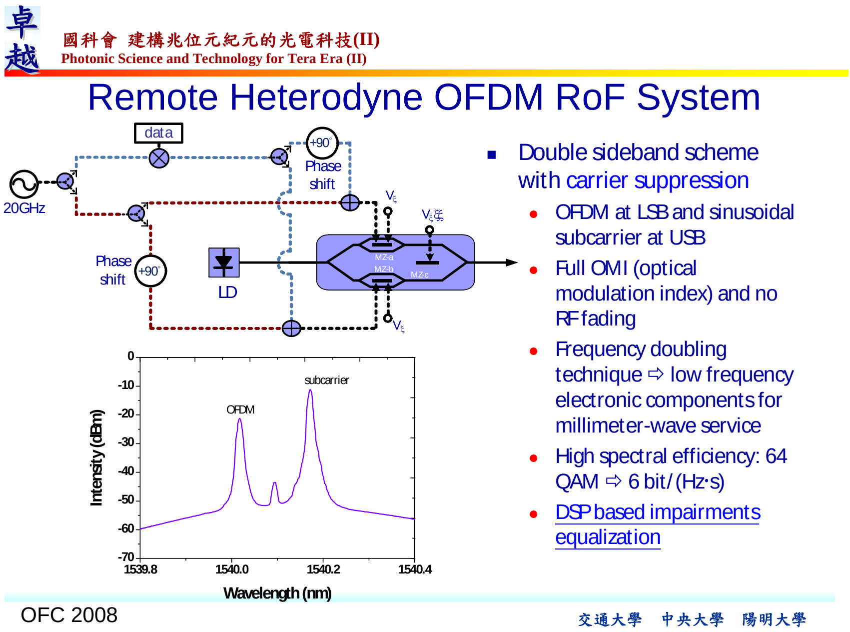


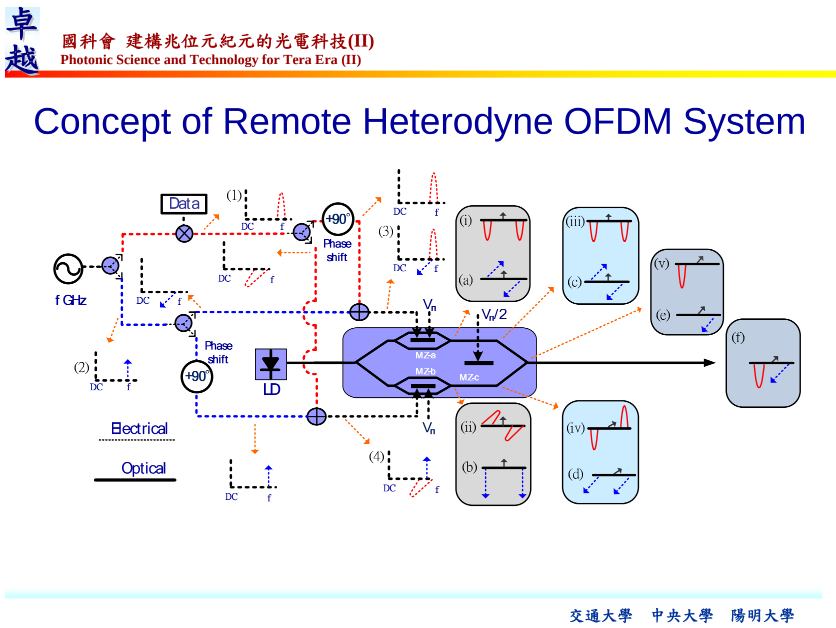
Recently we have also made important breakthrough on the tunable QD VCSEL slow light devices. The achieved bit-rate*delay-time product was the highest among the similar semiconductor devices. Although still not sufficient for optical buffer applications, they may find use in some signal processing applications.



II. Novel Optical Networking Architectures & Technologies :

We have developed a frequency doubling technique for generating complicated Radio-over-Fiber modulation signals that are required in hybrid wireless/fiber access network systems[20-21]. The trends for wireless communication have been moving from the present few GHz frequency band to several tens GHz (i.e., 60GHz). The direct electronic generation of RF modulation signals at frequencies higher than 40GHz is still expensive and inefficient. By the optical modulation frequency doubling technique we develop, we are able to generate the RF modulation signals inside the optical fiber by using only the lower frequency electronics. The technique is based on the interference cancellation effects of a jumbo optical modulator module illustrated in the following two figures.

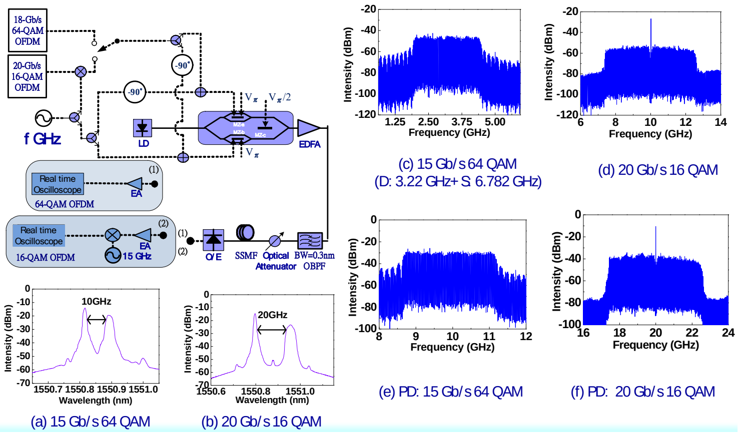




Examples of generated QAM OFDM signals at 15 or 20GHz and their performance are illustrated in the following three figures.

卓越 國科會 建構兆位元紀元的光電科技(II)
Photonic Science and Technology for Tera Era (II)

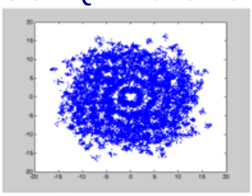
15 Gb/s 64-QAM and 20 Gb/s 16-QAM OFDM Signal

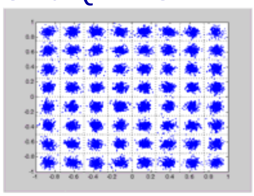


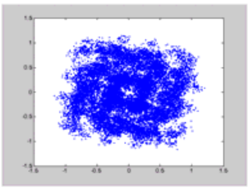
9 交通大學 中央大學 陽明大學

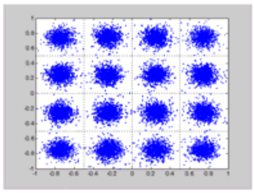
卓越 國科會 建構兆位元紀元的光電科技(II)
Photonic Science and Technology for Tera Era (II)

15 Gb/s 64-QAM and 20 Gb/s 16-QAM OFDM Signal


(a). 15 Gb/s 64-QAM before equalization


(b). 15 Gb/s 64-QAM after equalization


(c). 20 Gb/s 16-QAM before equalization


(d). 20 Gb/s 16-QAM after equalization

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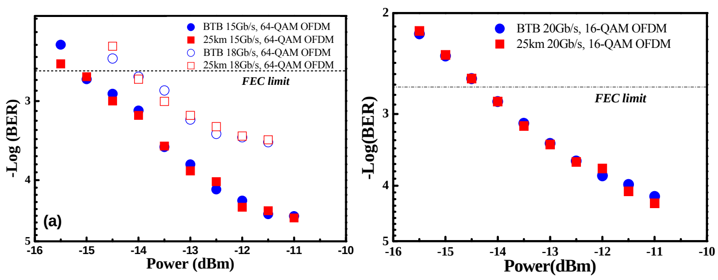
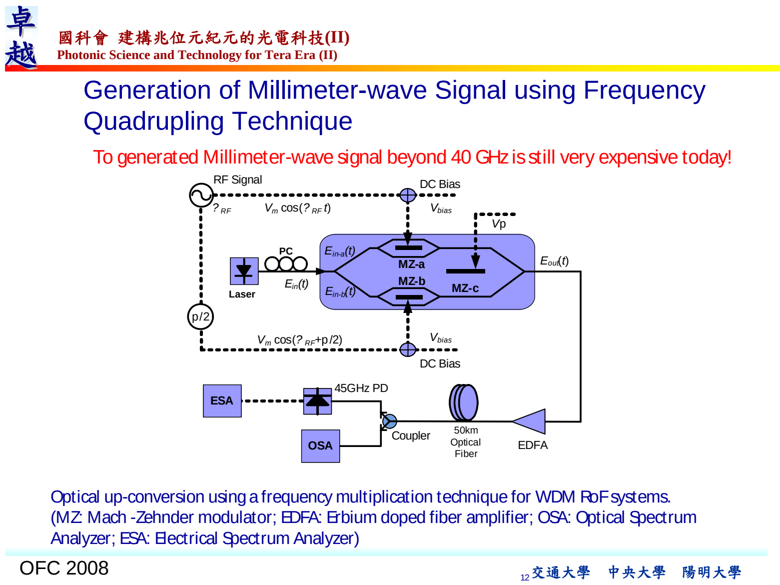
卓越 國科會 建構兆位元紀元的光電科技(II)
Photonic Science and Technology for Tera Era (II)

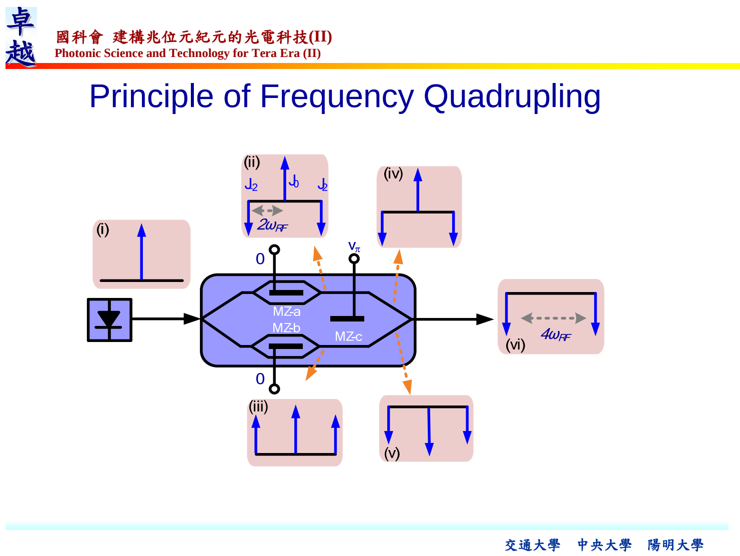
BER for 18 Gb/s 64-QAM and 20 Gb/s 16-QAM OFDM Signal

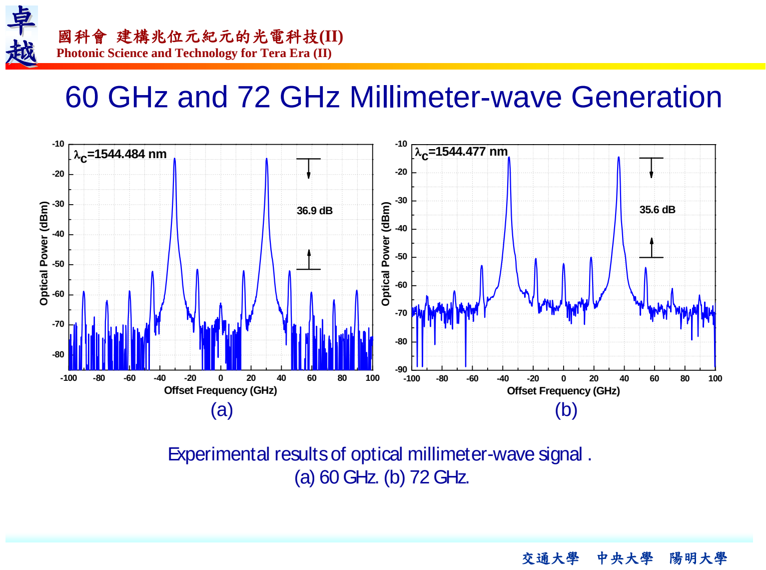


交通大學 中央大學 陽明大學

We have also further developed a frequency quadrupling technique illustrated in the following three figures and have successfully demonstrated the generation of 60 an 72 GHz microwave signals.

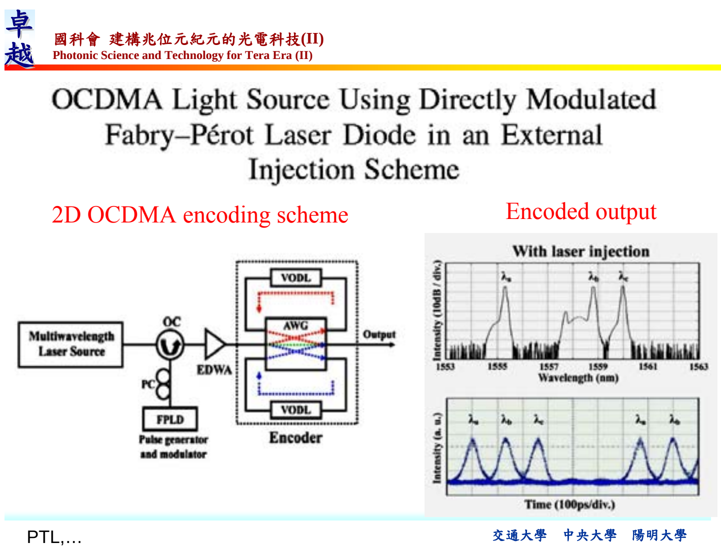






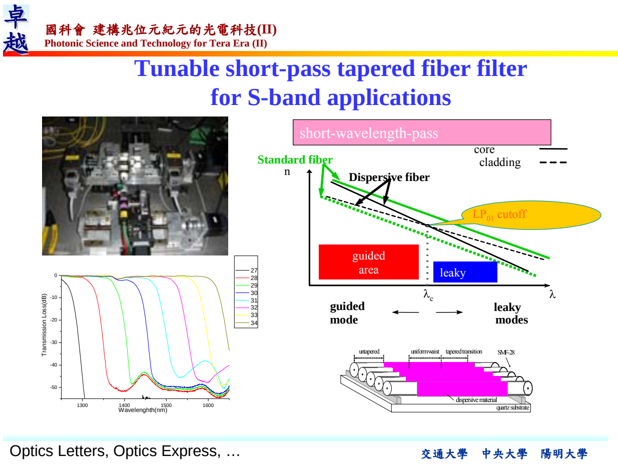
The above techniques have been employed to develop new hybrid wireless/fiber access networking system [23-24]. One of the main advantages is that no narrowband optical filtering is required.

We have also developed several new techniques for other types of optical access networks. They include the Passive Optical Networks (PON) and the Optical Code Division Multiple Access Networks (OCDMA) [25-28]. The following figure illustrates the developed new 2D OCDMA light sources by external injection of a semiconductor Fabry-Perot laser.

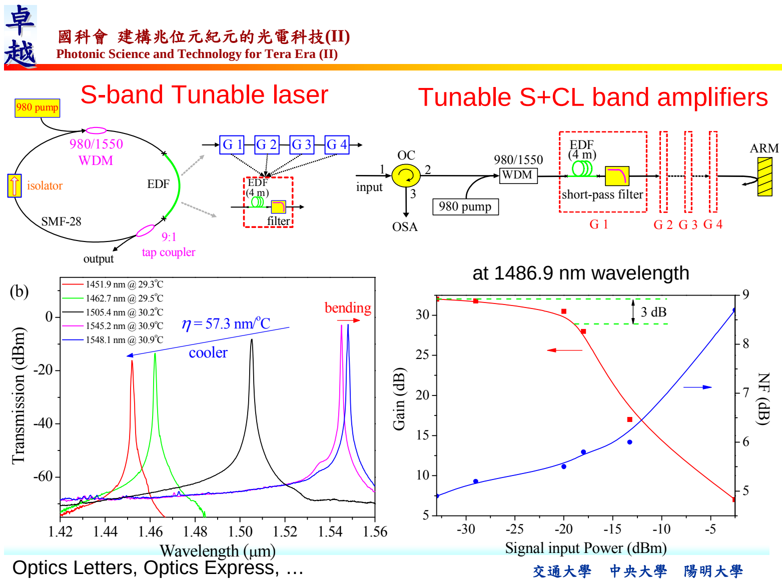


III. Novel Fiber Devices and Laser Sources :

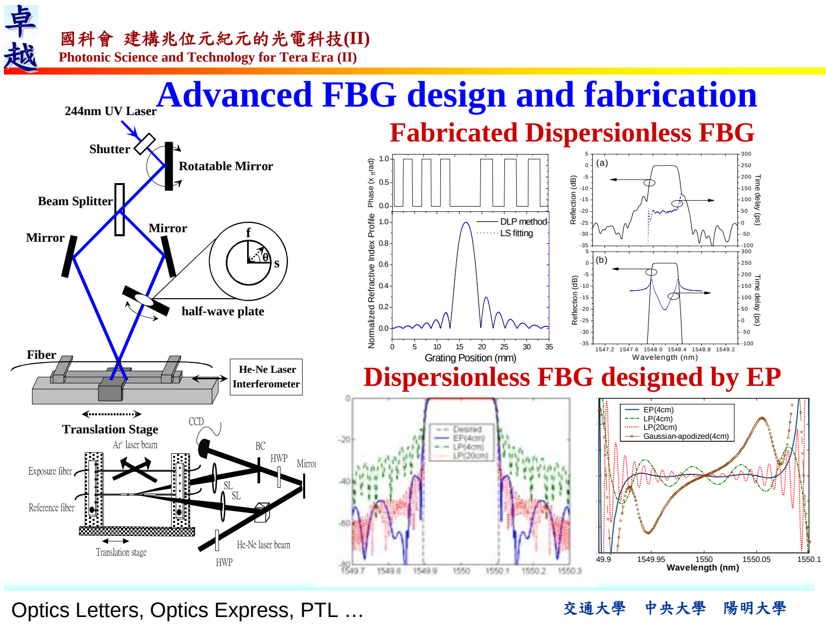
We have developed several new types of fiber devices, fiber amplifiers, and fiber lasers [33-37] One example is a novel tunable Er-doped fiber amplifiers covering S and C + L bands over 1490-1610 nm based on discrete fundamental-mode cutoff filters. [36] We demonstrate thermo-optically tunable Er3+-doped fiber amplifiers covering S- and C + L-bands (1490 ~ 1610 nm) using fundamental-mode cutoff filters discretely located in a 17.5-m-long standard Er3+-doped fiber. The maximum signal gains are measured to be 18.92 dB, 37.18 dB, and 15.19 dB with 980 nm pump power of 135 mW in S-, C-, and L-bands, respectively. The principle of the fiber filters is based on the fundamental mode cutoff mechanism illustrated in the following figure:



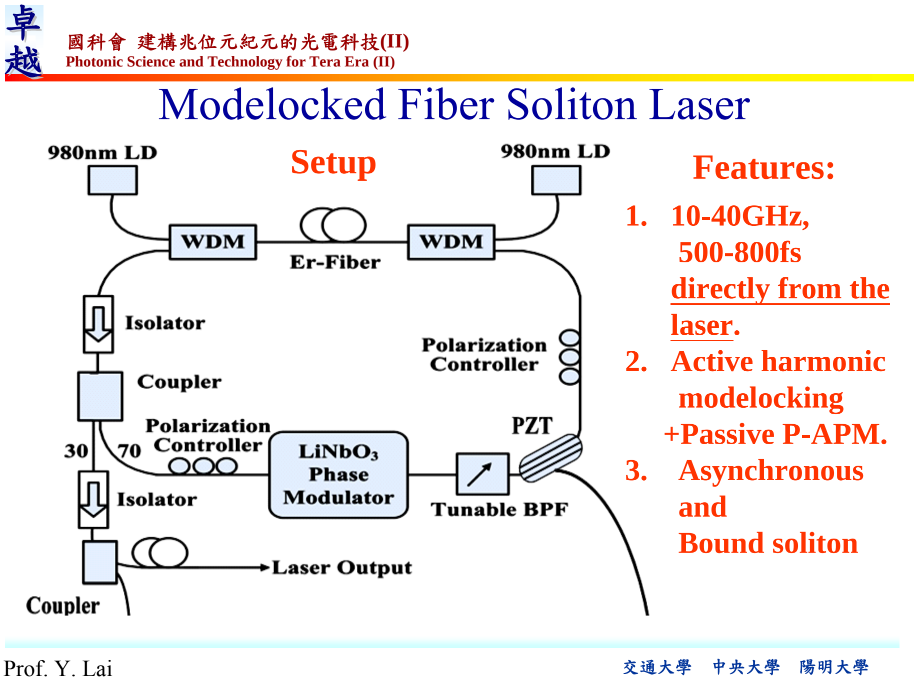
The achieved performance of the S-band amplifiers and lasers are illustrated below. We demonstrate a widely tunable fiber ring laser over 1451.9 ~ 1548.1 nm with tuning efficiency as high as 57.3 nm/°C using a 16-m-long standard silica-based erbium-doped fiber under 980-nm pump power of 208 mW. In principle, such a technique can be applied to other fiber laser systems to achieve shorter amplifying/lasing wavelengths that can not be achieved by conventional methods. In particular, the achieved lasing wavelength can be as short as 1451.9nm, which should be the shortest lasing wavelength of Er-fiber lasers reported to-date. Such a wavelength range is of particular interest to biomedical applications. This is why the paper is selected by the Virtual Journal of Biomedical Optics.[33]

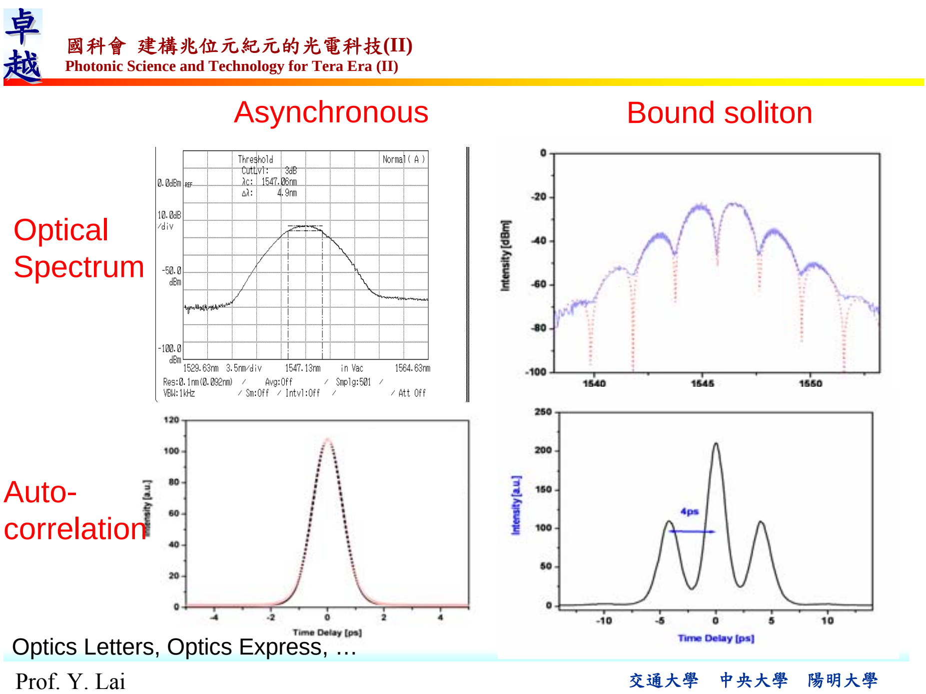


At NCTU we have established the best advanced fiber Bragg grating (FBG) fabrication platform in Taiwan and have developed several advanced FBG design and fabrication techniques.[29-32]



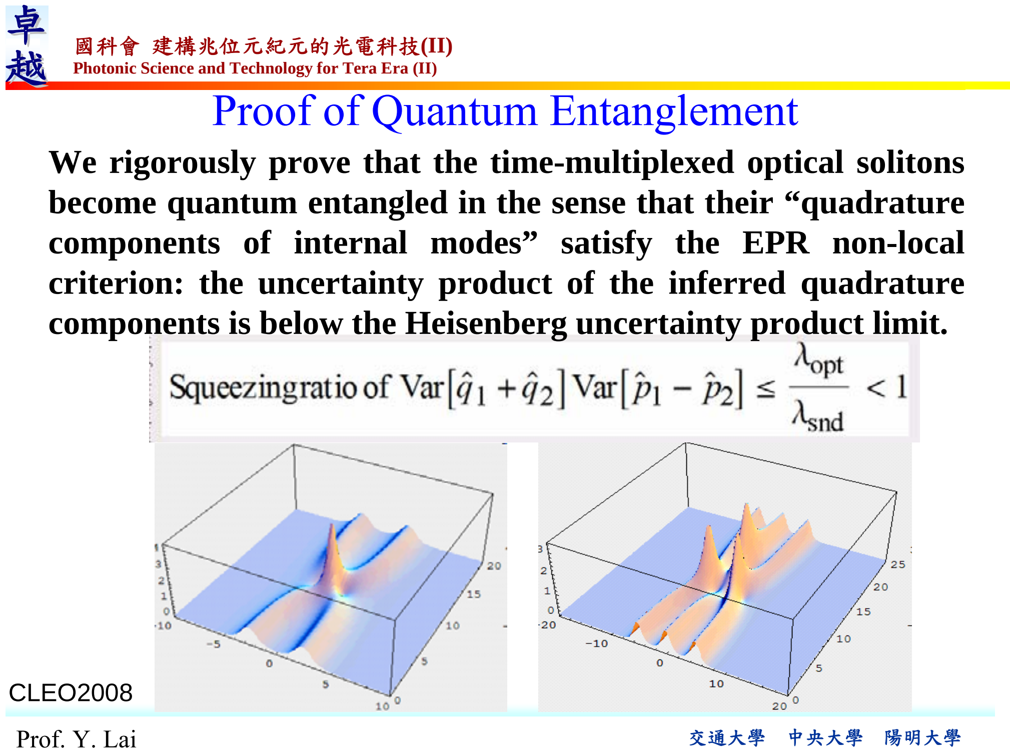
We have also developed several new types of high-repetition-rate modelocked fiber soliton lasers and studied their laser dynamics.[38-40] In particular, we have observed new bound soliton phenomena in a high-repetition rate modelocked fiber soliton laser. The time separation of the bound solitons can be modulated by adjusting the RF driving power. This property should be useful for implementing new applications with this new type of bound pulse sources.

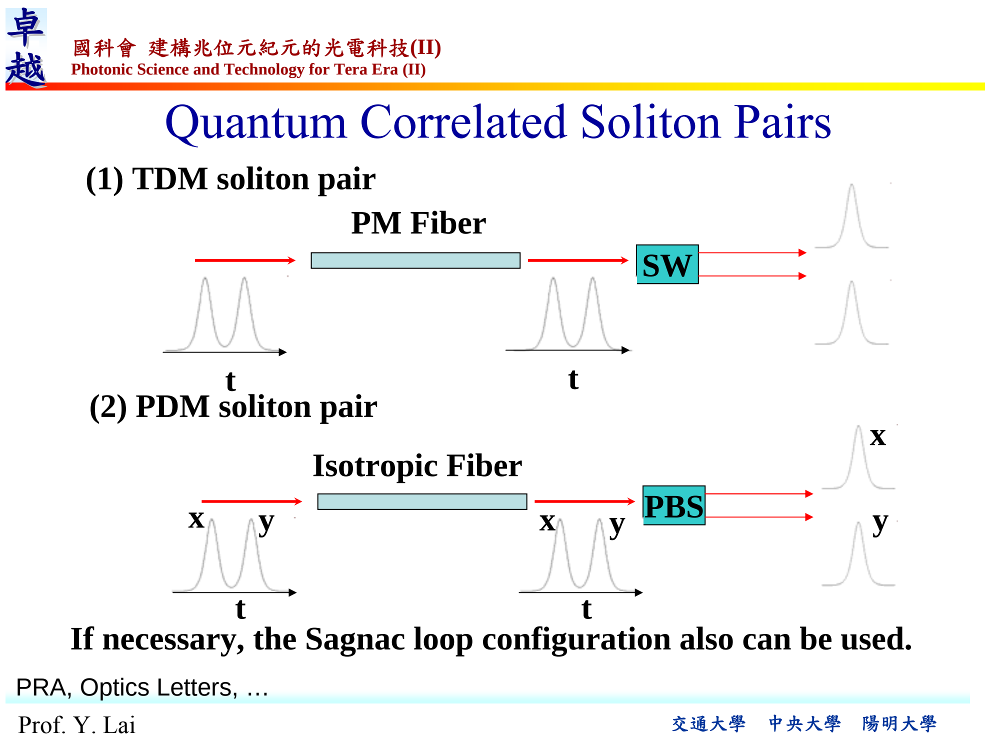




IV. Novel Theories & Applications :

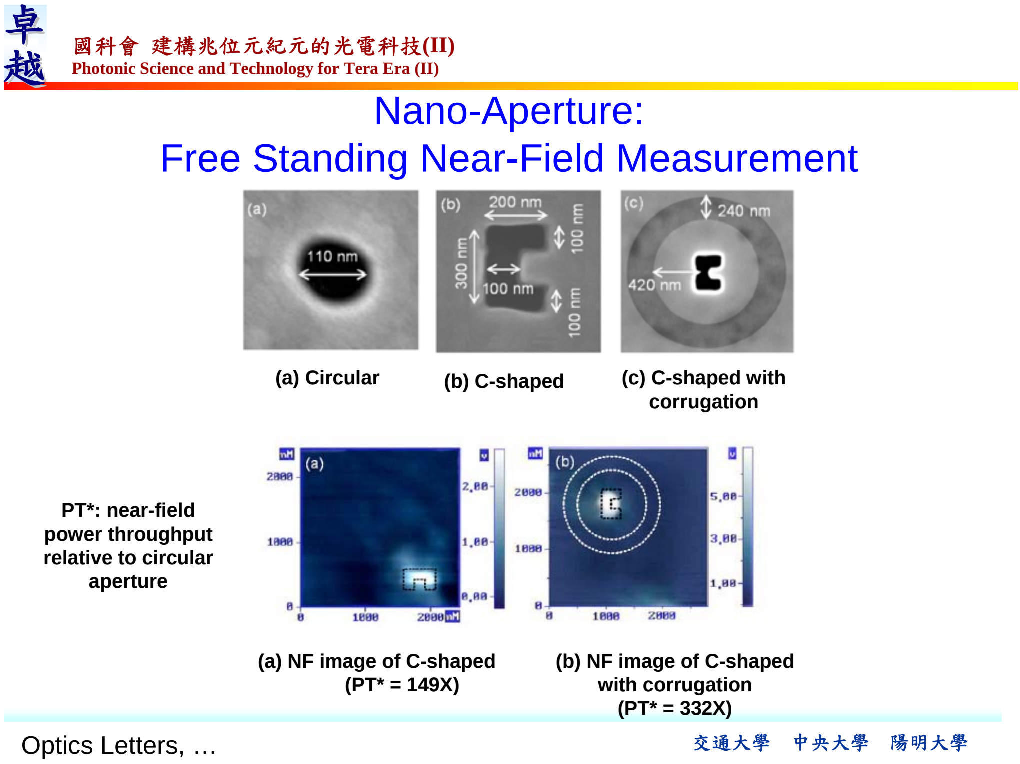
We have pioneered the development of the quantum theory for soliton squeezing, correlation, and entanglement.[41-44] We show for the first time that the solitons after nonlinear interaction are indeed quantum mechanically entangled. This should open new ways for generating quantum entangled light states.





B. <u>Next generation optical storage technologies</u>

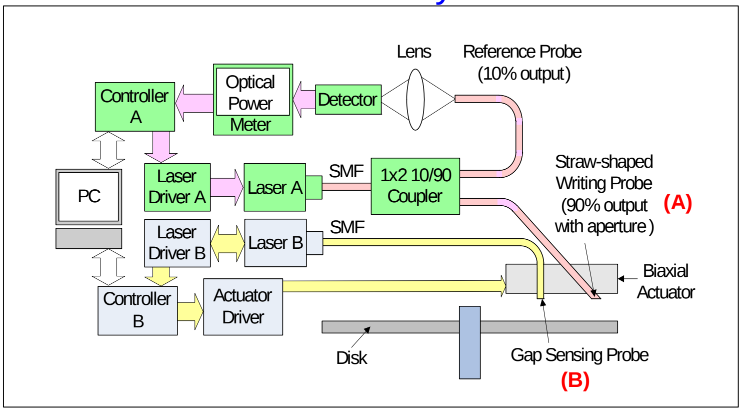
We have studied the power throughput enhancement effects of nano-aperture[45, 50]. We presented a ridged aperture encircled by a groove to allow the hybrid effect of coupling surface plasmon resonance to a propagating wave. This great improvement was demonstrated by its higher power throughput of 0.32 in the far field, a factor of 1.88 to the single ridged aperture that provided a signal-to-noise ratio of 20 dB in the near field.



We demonstrated a novel fiber-based near-field optical head consisting of a straw-shaped writing probe and a flat gap sensing probe [46]. The strawshaped probe with a C-aperture on the end face exhibits enhanced transmission by a factor of 3 orders of magnitude over a conventional fiber probe due to a hybrid effect that excites both propagation modes and surface plasmon waves. In the gap sensing probe, the spacing between the probe and the media surface functions as an external cavity. The high sensitivity of the output power to the change in the gap width is used as a feedback control signal.[48] We characterize and design the straw-shaped writing probe and the flat gap sensing probe. The dual-probe system is installed on a conventional biaxial actuator to demonstrate the capability of flying over a disk surface with nanometer position precision. [46]

卓越 國科會 建構兆位元紀元的光電科技(II)
Photonic Science and Technology for Tera Era (II)

Dual-probe Integrated Near-Field Fiber Head System



A. Writing probe: high transmission through a nanoaperture by hybrid resonant effect.
B. Servo probe: air gap as an external cavity modulation to obtain positioning signal.

Optics Express, …

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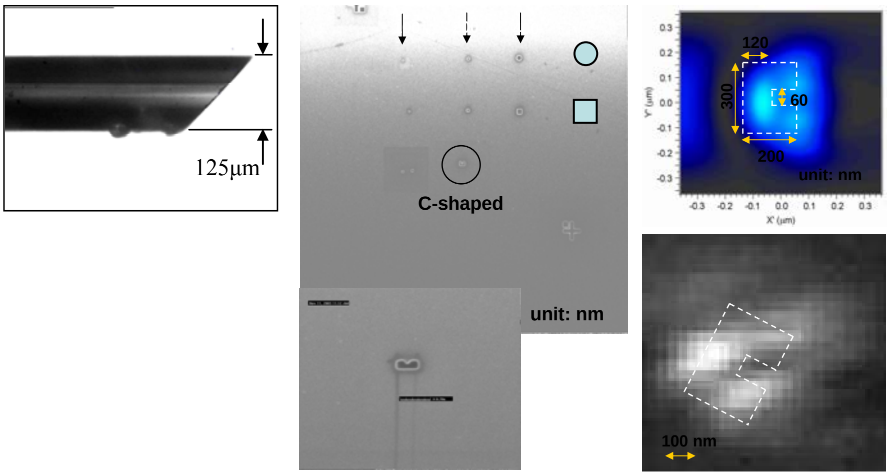
卓越 國科會 建構兆位元紀元的光電科技(II)
Photonic Science and Technology for Tera Era (II)

C-shaped Nano-aperture as Writing Probe



Optics Express, …

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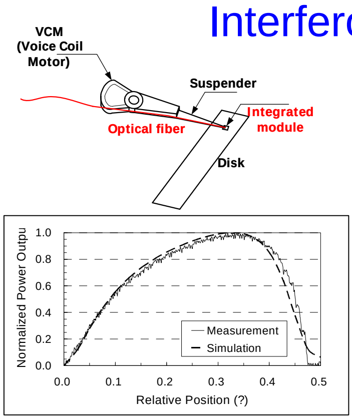
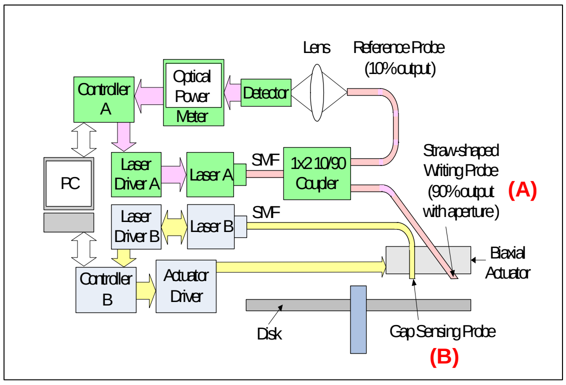
卓越 國科會 建構兆位元紀元的光電科技(II)
Photonic Science and Technology for Tera Era (II)

Active Gap Servo by Self-mixing Interferometric Feedback





- Self-mixing interferometric signal used as feedback signal
- Laser sensor installed on bi-axial actuator
- Controlling system designed for gap servo

JLT, …

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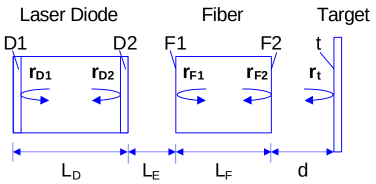
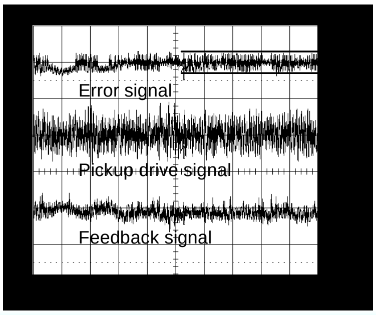
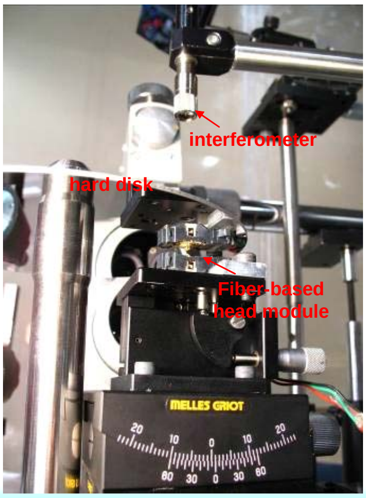
Photonic Science and Technology for Tera Era (II)

Near-Field Servo Control for Nanoscaled Position





@1500rpm



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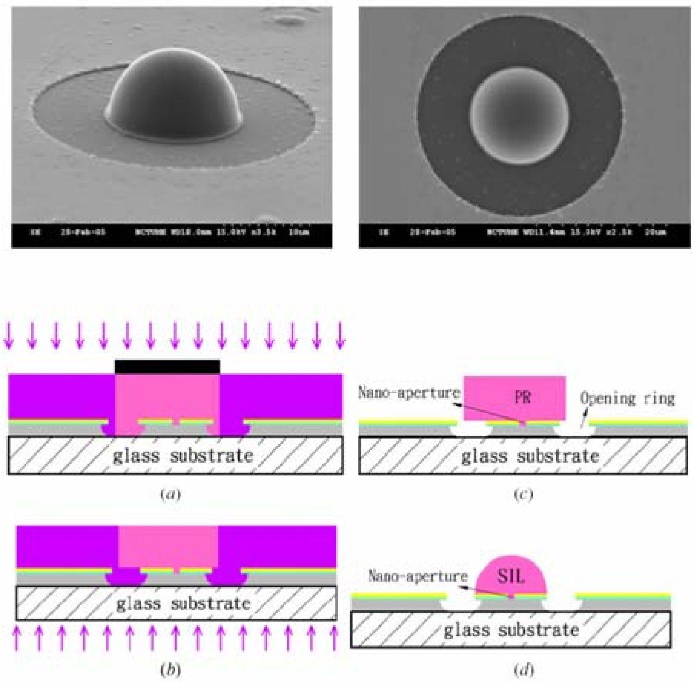
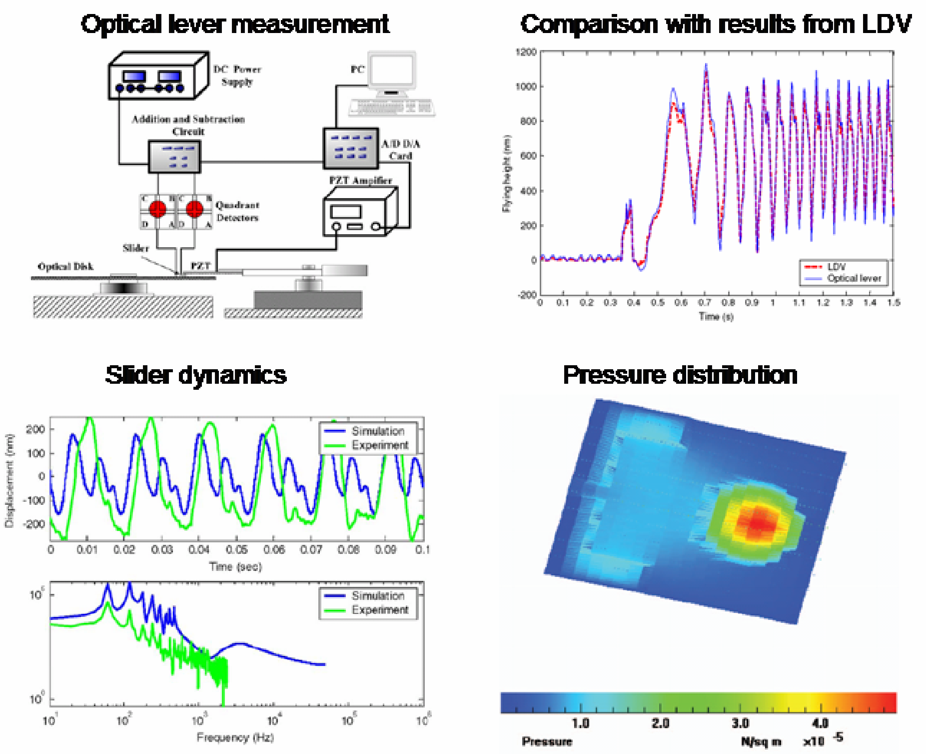
For the self-alignment process, two types of nano-aperture, circular and C shapes, are fabricated by Focused Ion Beam (FIB) to combine with SIL/SSIL formed by thermal reflow. Also, several novel micro actuators made of metal and polymer are developed, including a fabrication platform for three-dimensional polymer microstructures. Furthermore, based on extrusion and surface tension modulation techniques, a novel fabrication method to fabricate SILs on suspended cantilever array is successfully demonstrated. From the measurements of the power throughput and spot size, the proposed self-alignment process is successfully verified. For example, the φ15μm SIL/φ329nm circular aperture component is calibrated and found to enhance throughput 168%, comparing with that of φ329nm circular aperture alone. Furthermore, the throughput of 303nm×205nm C-shaped aperture/φ15μm SIL component can be enhanced 2443.8%, comparing with that of φ148nm circular aperture alone. These results verify the feasibility of the proposed self-aligned process [51].



For Near-field flyability, computational results show that grooved disks generate smaller pressure than smooth disks since grooves can accommodate air molecules and tune air pressure.[62] Further, flying higher makes pressure magnitudes closer between grooved disks and smooth disks in negative pressure area on slider bottoms. The proposed computational method facilitates pickup head design and improves head flyability during data read/write [56-61]. Experiments are carried out to demonstrate that the proposed controller performs better in flying height control than an optimal sliding mode controller. Accordingly, the controller can achieve stable flying height control in the presence of certain frequency vibration of optical disks. The media in near-field optical disk drives is usually made of glass or polycarbonate, which may generate significant deformation arisen from disk rotation. Using the advanced control method developed in this study can maintain stable and constant flying height, which is required in near-field data reading/writing. An optical lever method using only photo detectors for measuring flying height is applied to the flying head experiments. The results are validated by comparing with those from laser Doppler interferometers (LDV).



4. A Summary of the Post-Project Plan

Subproject 2:

A. Next generation optical communication technologies

I. Novel Optical Transmission & Processing :

We will continue to investigate the new modulation format techniques for achieving high transmission efficiency and/or high networking efficiency. The established fiber circulating loop testbed will be continuingly upgraded to serve as the platform for experimentally verifying the newly developed idea and techniques. System applications of the new newly developed tunable slow light devices based on quantum dot VCSELs will be investigated. Possible applications of the new modulation format techniques to hybrid (baseband digital+radio) optical transmission and quantum key distribution systems will continue to be investigated.

II. Novel Optical Networking Architectures & Technologies :

We will intensively develop the hybrid wireless/fiber access networking systems based on our unique frequency multiplication schemes. In particular, the 60GHz wireless systems have been intensively investigated by the researchers from the wireless side. We are hoping that our optical schemes can contribute to real advances by cooperating with these electronics techniques.

III. Novel Fiber Devices and Laser Sources :

Advanced design and fabrication techniques of all-fiber devices will be continuingly investigated. Existing platforms for fiber grating exposure, fiber side-polishing, fiber fusion tapering, …, will be continuously upgraded for fabricating new fiber devices. The performance of the modelocked fiber soliton laser will be further studied and improved. Possible applications of modelocked fiber lasers on classical/quantum communication will be investigated.

IV. Novel Theories & Applications :

Quantum theory of soliton entanglement generation will be developed further to take into account the possible applications on quantum communication and quantum information. Different types of optical soliton phenomena will be investigated to explore new possibilities for classical/quantum communication applications.

B. Next generation optical storage technologies

In the next phase, we will setup an experimental bench to study the surface plasmon polariton (SPP) effects and to ensure the interaction between the incident optical waves and the nanostructure in the near-field optical region. In addition, fluid dynamic analyses in flying will be further carried out to investigate what geometry of sliders with optical fiber and waveguide is optimal when considering dust removal, since the dust between solid immersion lens and disks may cause friction and damage to the lens. Finally, MEMS-based devices combining solid immersion lens and nanoapertures will continue to be investigated.

5. INTERNATIONAL COOPERATION ACTIVITIES (OPTIONAL)

Subproject 2:

Optical Communication:

- Prof. J. Chen cooperated with Prof. Y.R. (Ray) Chen in the Department of Electrical Engineering at University of Maryland Baltimore County (UMBC) on the development of PLC OADM module.
- Prof. J. Chen and Prof. S. Chi cooperated with Prof. G.K. Chang in the Department of Electrical Engineering at Georgia Institute of Technology (GIT) on the development of bi-directional fiber transmission and other new optical transmission/networking techniques.

Optical Storage:

- Prof. C. H. Tien cooperated with Prof. Ed. Schlesinger in the Department of Electrical Engineering at Carnegie Mellon University on the demonstration of the proposed dual fiber-based near-field optical head in the spin stand.
- Prof. W. Hsu cooperated with the Laser Micromachining group at Canada NRC Integrated Manufacture Technology Institute on the development of the micro actuators.

VI. APPENDIX I:MINUTES FROM PROGRAM DISCUSSION MEETINGS

VII. APPENDIX II:

1. PUBLICATION LIST（CONFERENCES, JOURNALS, BOOKS, BOOK CHAPTERS, etc.）

Sub-Project2:

Representative Publications (sorted according to research topics):

[Bi-directional fiber transmission and novel interleaver applications]

1. M. F. Huang, J. Chen, J. Yu, S. Chi and G.-K. Chang "A Novel Dispersion-free Interleaver for Bi-directional DWDM Transmission Systems," IEEE J. Lightwave Technol., Vol. 25, No. 11, pp. 3543- 3554, 2007.
2. M.-F. Huang, K.-M. Feng, J. Chen, T.-Y. Lin, C.-C. Wei, S. Chi, "Wavelength-Interleaving Bidirectional Transmission System Using Unidirectional Amplification in a 5x100 km Recirculating Loop", IEEE Photonics Technol. Lett., pp. 1326-1328, 2006.
3. M.F. Huang, J. Chen, K. M. Feng, et al., "210-km Bidirectional transmission system with a novel four-port interleaver to facilitate unidirectional amplification", IEEE PHOTONICS TECHNOLOGY LETTERS 18 (1-4): 172-174, 2006.
4. K. M Feng, M. F Huang, C. C. Wei, C. Y Lai, T. Y. Lin, J. H. Chen and S. Chi, "Metro Add/Drop Network Applications of Cascaded Dispersion-Compensated Interleaver Pairs Using a Re-circulating loop", IEEE Photonics Technol. Lett., vol.17, pp.1349-1351, June 2005.
5. J. Chen, "Dispersion-Compensating Optical Digital Filters for 40-Gb/s Metro Add–Drop Applications", IEEE Photonic Technol. Lett., pp. 1310- 1312, 2004.

[Novel all-optical signal processing (slow lights, Optical 2R, PLC ROADM ….)]

6. P.C. Peng, C.T. Lin, H.C. Kuo, W.K. Tsai, J.N. Liu, S. Chi, S.C. Wang, G. Lin, H.P. Yang, K.F. Lin, J.Y. Chi, "Tunable slow light device using quantum dot semiconductor laser", Optics Express 14 (26): 12880-12886, 2006.
7. H.C. Chien, C.C. Lee, C.T. Lin CT, et al., "EDFA-free all-optical 2R regeneration using a compact self-seeded Fabry-Perot laser diode", IEEE PHOTONICS TECHNOLOGY LETTERS 18 (9-12): 1112-1114, 2006.
8. H.C. Chien, C.C. Lee, S. Chi, "An all-optical 2R regenerator using a compact self-seeded Fabry-Perot laser diode incorporated in a bidirectional EDFA", IEEE PHOTONICS TECHNOLOGY LETTERS 18 (9-12): 1344-1346, 2006.
9. H.C. Chien, C.C. Lee, Y.M. Chen, et al., "All-optical 2R regeneration based on a compact self-seeded Fabry-Perot laser diode with an embedded fiber Bragg grating", IEEE PHOTONICS TECHNOLOGY LETTERS 18 (1-4): 559-561, 2006.
10. C.-C. Wei and J. Chen, "Study of Differential Cross-Polarization Modulation in Semiconductor Optical Amplifier", Optics Express, vol. 13, No. 21, pp. 8442-8451, Oct. 2005.
11. C.C Wei, M. F. Huang, J.H. Chen, "Enhancing the Frequency Response of Cross Polarization Wavelength Conversion", IEEE Photonics Technol. Lett., vol.17, pp. 1683-1685, Aug. 2005.
12. M.-F. Huang, J. Chen, K.-M. Feng, C.-Y. Lai, C.-C. Wei, T.-Y. Lin, S. Chi, Z. Zhu, Y. J. Chen, Y.-C. Huang and S.-J. Chang, "Add/Drop Applications in Fiber Ring Networks Based on a Reconfigurable Optical Add/Drop Multiplexer in a Re-circulating Loop", Optics Communications, vol. 267, November, pp. 113-117, 2006.

[Cost-effective/high-performance duobinary/DPSK/…. Transmission]

13. C.-C. Wei, J. Chen, and Y. Chen, "Evaluation the Performance Improvement of DPSK Signals by Amplitude Regeneration and Phase Noise Suppression", to be published at Optics Lett., 2008.
14. W.R. Peng, S. Chi, "Quantum limit of optimum four-level ASK signals with direct detection optically preamplified receivers," OPTICS EXPRESS, 15 (11): 6790-6797 MAY 28, 2007.
15. C. C. Wei and J. Chen,, "Convergence of phase fluctuation induced by intrachannel four-wave mixing in differential phase-shift keying transmission systems via phase fluctuation averaging", Optics Lett., no. 10, pp. 1217-1219, May, 2007.
16. C. T. Lin, W. R. Peng, P. C. Peng, J. Chen, C. F. Peng, B. S. Chiou, and S. Chi, "Simultaneous Generation of Baseband and Radio Signals Using Only One Single-Electrode Mach–Zehnder Modulator With Enhanced Linearity," IEEE Photon. Technol. Lett., vol. 18, pp. 2481-2483, 2006.
17. C.C. Wei, J. Chen, "Convergence of phase noise in DPSK transmission systems by novel phase noise averagers", Optics Express, vol. 14, No. 21, pp. 9584-9593, 2006.
18. Y.-C. Lu, J. Chen, K.-M. Feng, P.-C. Yeh, T.-Y. Huang, W.-R. Peng, M.-F. Huang, and C.-C. Wei,

"Improved SPM Tolerance and Cost-Effective Phase-Modulation Duobinary Transmission over 230 km Standard Single-Mode Fiber Using a Single Mach-Zehnder Modulator", IEEE Photonics Technol. Lett., vol.17, 2754-2756, Dec. 2005.
19. W.-R. Peng, Y.-C. Lu, J. Chen, S. Chi, "Encoding ASK labeled CSRZ-DPSK payload by using only one dual-drive Mach-Zehnder Modulator with enhanced label performance", IEEE Photonics Technol. Lett., vol.17, p. 2227-2229, Oct. 2005.

[Hybrid wireless/fiber access networking]

20. C.-T. Lin, Y.-M. Lin, J. Chen, S.-P. Dai, P. T. Shih, P.-C. Peng, and S. Chi, "Optical Direct-Detection OFDM Signal Generation for Radio-Over-Fiber Link Using Frequency Doubling Scheme with Carrier Suppression", to be published at Optics Express, 2008.
21. C.-T. Lin, S.-P. Dai, J. Chen, P. T. Shih, P.-C. Peng, S. Chi, "A Novel Direct Detection Microwave Photonic Vector Modulation Scheme for Radio-Over-Fiber System", to be published at IEEE Photon. Technol. Lett., 2008
22. C.T. Lin, P. T. Shih, J. Chen, W.-Q Xue, P.-C. Peng, S. Chi, "Optical Millimeter-Wave Signal Generation Using Frequency Quadrupling Technique and No Optical Filtering", to be published at IEEE Photon. Technol. Lett., 2008
23. C.T. Lin, P. T. Shih, J. Chen, P.-C. Peng, S.-P. Dai, W.-J. Jiang, W.-Q Xue, and S. Chi, "Cost-Effective Multi-Services Hybrid Access Networks with no Optical Filter at Remote Nodes", to be published at IEEE Photon. Technol. Lett., 2008
24. C. T. Lin, J. Chen,, P. Peng, C. Peng, W. Peng, B. Chiou and S. Chi, "Hybrid optical access network integrating fiber-to-the home and radio-over-fiber systems", IEEE Photon. Technol. Lett., vol. 19, pp. 610-612, Apr., 2007.

[Optical access networking (PON, OCDMA, …)]

25. W.R. Peng, W.P. Lin, S. Chi, "Improved fiber Bragg grating array OFFH-CDMA system using a novel frequency-overlapping multigroup method", JOURNAL OF LIGHTWAVE TECHNOLOGY 24 (3): 1072-1081, 2006.
26. P.-C. Peng, W.-R. Peng; K.-M. Feng, H.-Y. Chiou, J. Chen; H.-C. Kuo, S.-C. Wang, S. Chi, "OCDMA light source using directly modulated Fabry-Perot laser diode in an external injection scheme", IEEE Photonics Technol. Lett., pp. 1103-1105, 2006.
27. C.H. Yeh, D.Z. Hsu, S. Chi, "Upstream power equalization in a gigabit passive optical network Source," OPTICS EXPRESS, 15 (8): 5191-5195 APR 16, 2007.
28. C.-H. Yeh, and S. Chi, "Optical fiber-fault surveillance for passive optical networks in S-band operation window," Optics Express, vol. 13, no. 14, p. 5494-5498, 2005.

[Complicated fiber Bragg grating devices: advanced design and fabrication]

29. K.-C. Hsu, L.-G. Sheu, K.-P. Chuang, S.-H. Chang and Y. Lai, "Fiber Bragg grating sequential UV-writing method with real-time interferometric side-diffraction position monitoring," Optics Express vol.13, No.10, p.3795, 2005.
30. K.-P. Chuang, L.-G. Sheu, and Y. Lai, "Complex fiber grating structures fabricated by sequential writing with polarization control", Optics Letters 29, pp.340-342 2004.
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32. C.-L. Lee and Y. Lai, "Optimal dispersionless fiber Bragg grating filter with shorter grating length and smoother dispersion profile", Optics Communications 235, pp.99-106, 2004.

[Novel tapered fiber devices, fiber amplifiers and fiber lasers]

33. N.K. Chen, C.M. Hung, S. Chi, Y. Lai, "Towards the short-wavelength limit lasing at 1450 nm over I-4(13/2)-> I-4(15/2) transition in silica-based erbium-doped fiber," OPTICS EXPRESS, Vol: 15, Pages: 16448-16456, 2007. (selected into Virtual Journal for Biomedical Optics, Vol. 3, Issue 1, January, 2008)
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36. N. K. Chen, K. C. Hsu, S. Chi, and Y. Lai, "Tunable Er3+-doped fiber amplifiers covering S and C + L bands over 1490-1610 nm based on discrete fundamental-mode cutoff filters," Opt. Lett. 31, 2842-2844, 2006..
37. N. K. Chen and S. Chi, "Influence of a holey cladding structure on spectral characteristics of side-polished endlessly single-mode photonic crystal fibers," Opt. Lett. 31, 2251-2253, 2006.

[High repetition rate modelocked fiber soliton lasers]

38. W. -W. Hsiang, C. -Y. Lin, and Y. Lai, "Stable new bound soliton pairs in a 10 GHz hybrid frequency modulation mode-locked Er-fiber laser," Opt. Lett. 31, 1627-1629, 2006.
39. W.-W. Hsiang, C.-Y. Lin, N.-K. Sooi, Y. Lai, “Long-term stabilization of a 10 GHz 0.8 ps asynchronously mode-locked Er-fiber soliton laser by deviation-frequency locking,” Optics Express 14, 1822-1828, 2006.
40. W.-W. Hsiang, C.-Y. Lin, M.-F. Tien, and Y. Lai, “Direct generation of 10 GHz 816 fs pulse train from an erbium-fiber soliton laser with asynchronous phase modulation,” Opt. Lett. 30, 2493-2495, 2005.

[Quantum squeezing and quantum entanglement of optical solitons]

41. R.-K. Lee, Y. Lai, and B. A. Malomed, "Photon-number fluctuation and correlation of bound soliton pairs in mode-locked fiber lasers,” Opt. Lett. 30, 3084-3086, 2005.
42. R.-K. Lee, Y. Lai, and B. Malomed, "Generation of photon-number entangled soliton pairs through interactions," Phys. Rev. A 71, 013816, 2005.
43. R.-K. Lee, Y. Lai, and Yu. S. Kivshar, “Quantum correlations in soliton collisions,” Phys. Rev. A 71, 053801 (2005).
44. R.-K. Lee, E. A. Ostrovskaya, Y. S. Kivshar, and Y. Lai, "Quantum-noises of matter-wave gap solitons," Phys. Rev. A 72, 033607, 2005.

[Nano-Aperture and Dual-probe near-field fiber head]

45. J.-Y. Fang, C.-H. Tien, and H.-P. D. Shieh, “Hybrid-effect transmission enhancement induced by oblique illumination in nano-ridge waveguide,” Opt. Exp., 15, 11741, 2007.
46. J.-Y. Fang, C.-H. Tien, and H.-P. D. Shieh, “Dual-probe near-field fiber head with gap servo control for data storage applications,” Opt. Exp., 15, 14619, 2007.
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3. Invention List

4. List of Workshops/Conferences Hosted by the Program

5. List of Personal Achievements of the PIs

祁甡教授：獲選為2007年教育部第十一屆國家講座主持人之一

6. List of Technology Transfers

7. List of Technology Services

VIII. APPENDIX III: LIST OF PUBLICATIONS IN "TOP"JOURNALS AND CONFERENCES

Sub-Project 2:

Summary:

[Top Journals]

Optics Letters-- 11

Optics Express-- 24

IEEE Photonics Technology Letters-- 27

IEEE Journal of Lightwave Technology—5

IEEE Journal OF Selected Topics in Quantum Electronics—1

IEEE Transactions--- 8

Physical Review --- 6

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Total: 82

[Top Conferences]

	2004	2005	2006	2007	2008	Total
OFC	1	2	3	4	6	16
CLEO	1	3	3	4	5	16
ECOC	1	3	3	3		10

In particular,

OFC 2008: 6 papers

CLEO 2008: 5 papers including 1 postdealine

International Journal papers:
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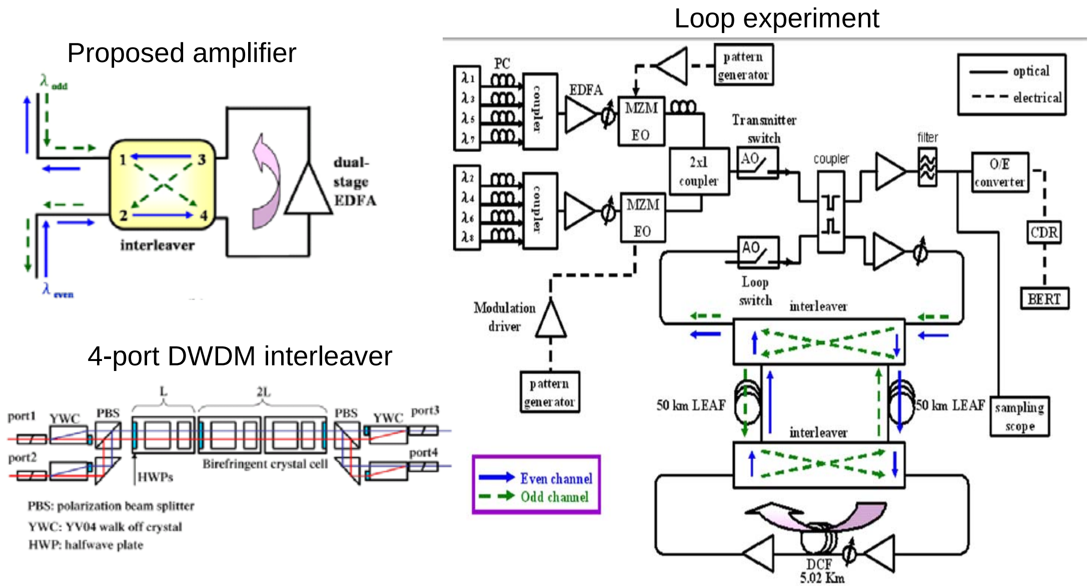
IX. Appendix IV: Slides on Science and Technology Breakthroughs

卓越 國科會 建構兆位元紀元的光電科技(II)
Photonic Science and Technology for Tera Era (II)

Low crosstalk bi-directional fiber transmission



JLT, PTL, …

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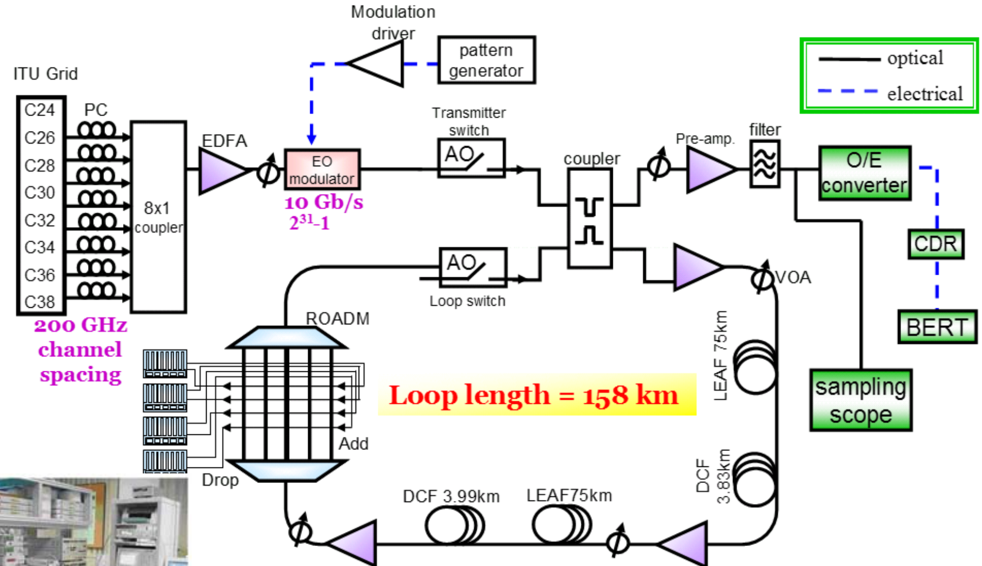
Fiber Circulating Loop Platform



PLC ROADM work was in cooperation with Prof. Y.R. Chen (UMBC) and ITRI.

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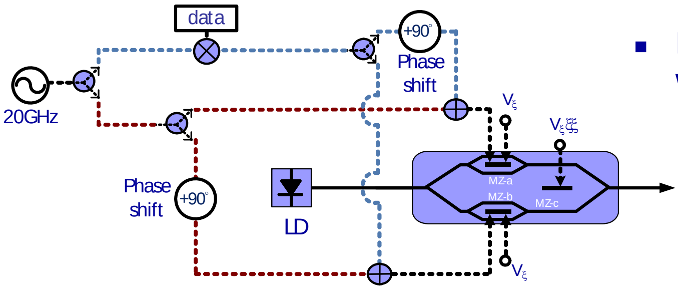
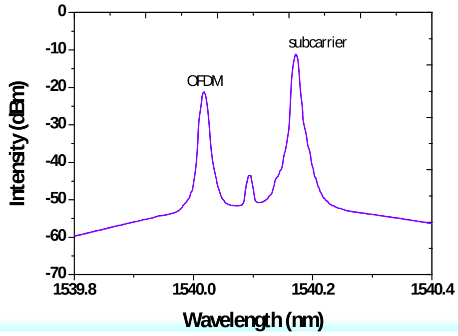
Remote Heterodyne OFDM RoF System





- Double sideband scheme with carrier suppression
  - OFDM at LSB and sinusoidal subcarrier at USB
  - Full OMI (optical modulation index) and no RF fading
  - Frequency doubling technique ⇨ low frequency electronic components for millimeter-wave service
  - High spectral efficiency: 64 QAM ⇨ 6 bit/(Hz·s)
  - DSP based impairments equalization

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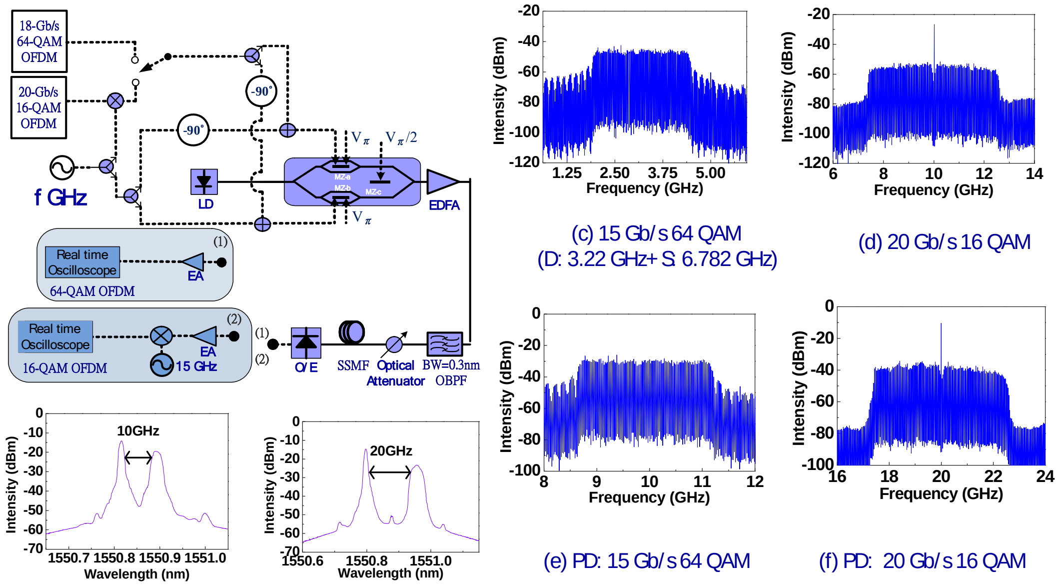
15 Gb/s 64-QAM and 20 Gb/s 16-QAM OFDM Signal



(a) 15 Gb/s 64 QAM

(b) 20 Gb/s 16 QAM

(c) 15 Gb/s 64 QAM (D: 3.22 GHz+ S: 6.782 GHz)

(d) 20 Gb/s 16 QAM

(e) PD: 15 Gb/s 64 QAM

(f) PD: 20 Gb/s 16 QAM

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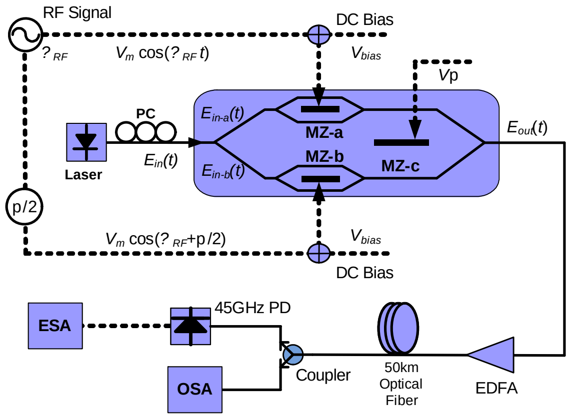
Generation of Millimeter-wave Signal using Frequency Quadrupling Technique

To generated Millimeter-wave signal beyond 40 GHz is still very expensive today!



Optical up-conversion using a frequency multiplication technique for WDM RoF systems. (MZ: Mach -Zehnder modulator; EDFA: Erbium doped fiber amplifier; OSA: Optical Spectrum Analyzer; ESA: Electrical Spectrum Analyzer)

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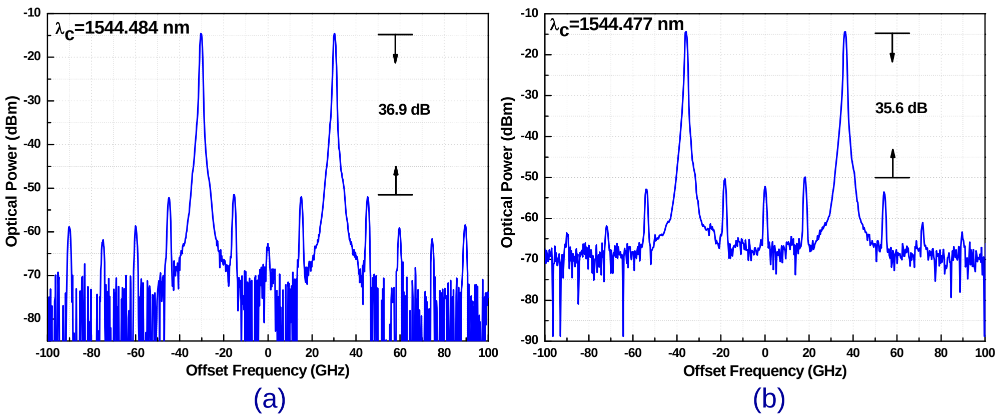
60 GHz and 72 GHz Millimeter-wave Generation



Experimental results of optical millimeter-wave signal .
(a) 60 GHz. (b) 72 GHz.

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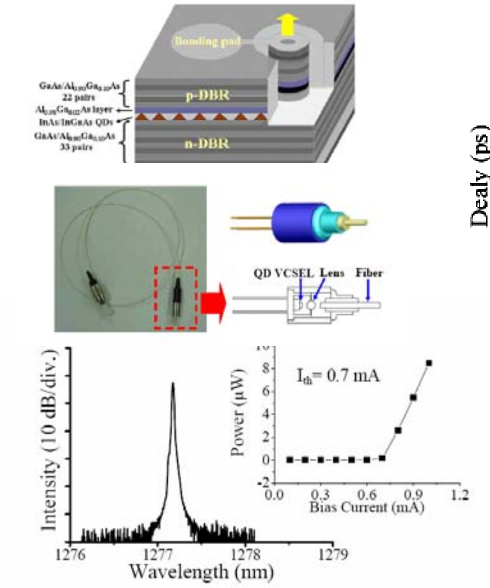
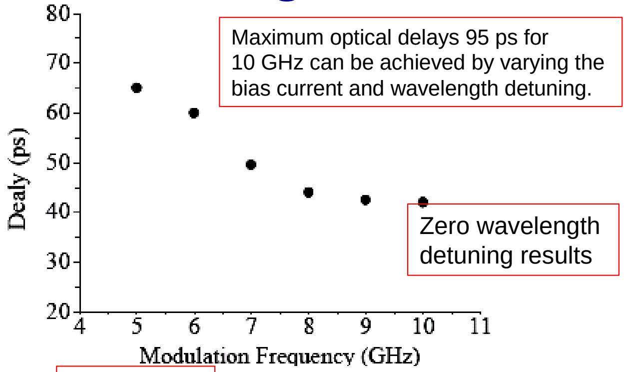
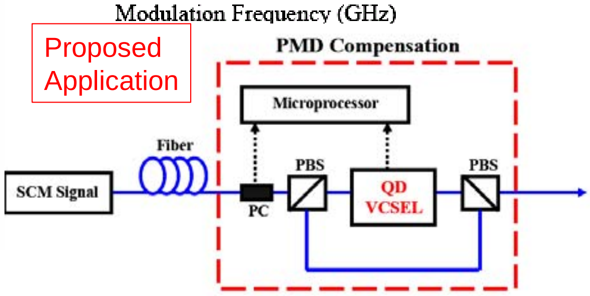
Tunable QD VCSEL slow light device







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NCTU (Prof. H.-C. Kuo, S. Chi…) + OES/ITRI

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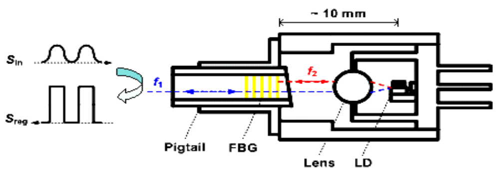
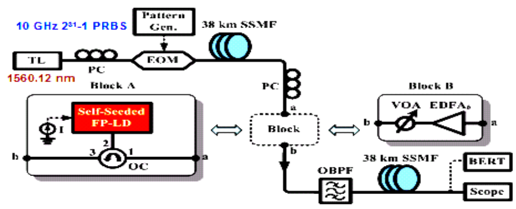
EDFA-Free, All-Optical 2R Regeneration Using a Compact Self-Seeded Fabry-Pérot Laser Diode

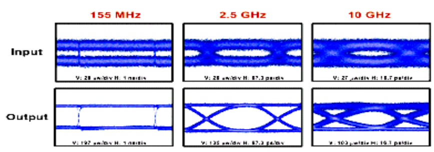


- Elegant and cost-effective
- Amplifier-free (8.3 dB gain)
- W/o wavelength conversion
- Data-rate transparent up to 10 Gb/s

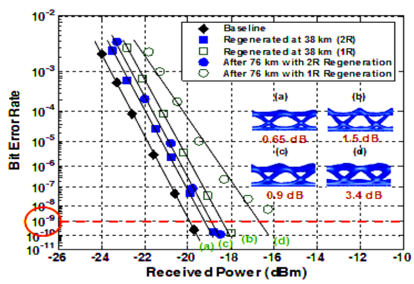
EDFA-Free Test Link over 76 km at 10 Gb/s



Data-Rate Transparent Up to 10 Gb/s



BER Performance and Eye Patterns



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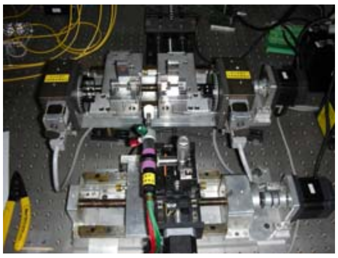
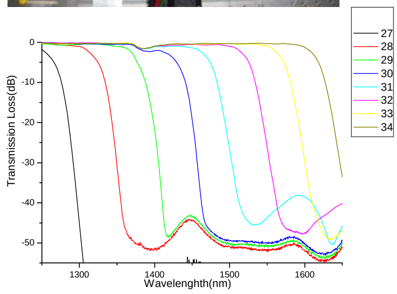
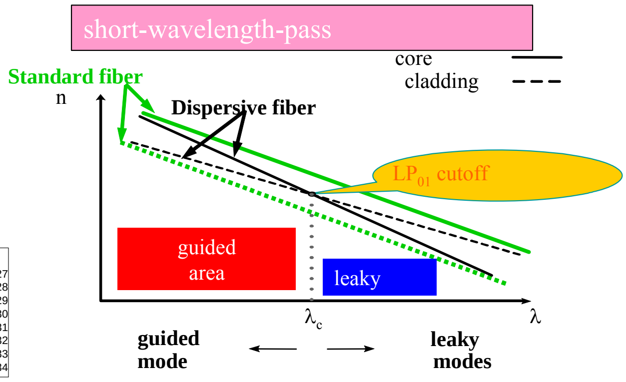
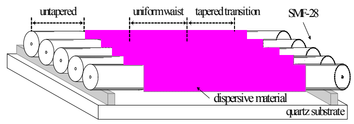
Tunable short-pass tapered fiber filter for S-band applications









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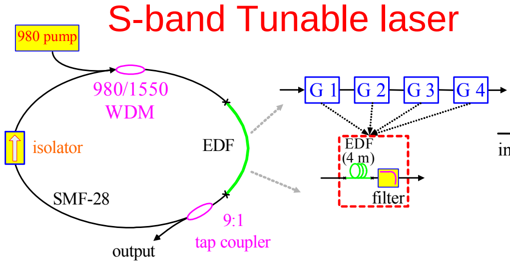
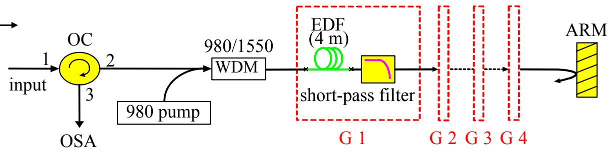
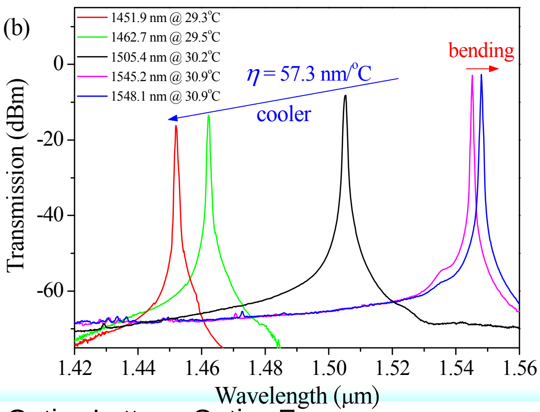
S-band Tunable laser

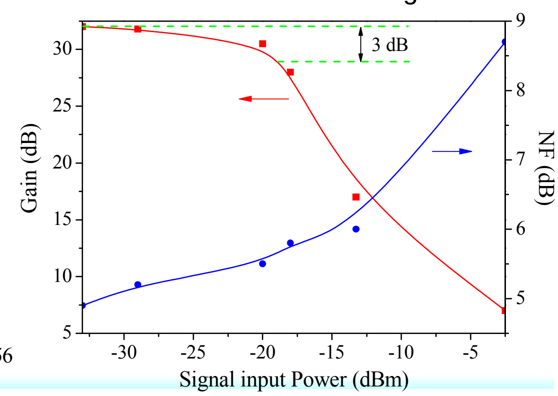


Tunable S+CL band amplifiers





at 1486.9 nm wavelength



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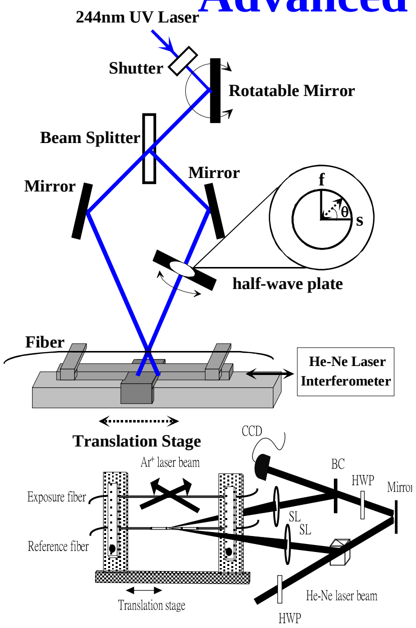
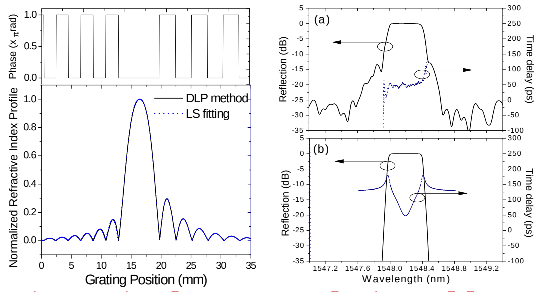
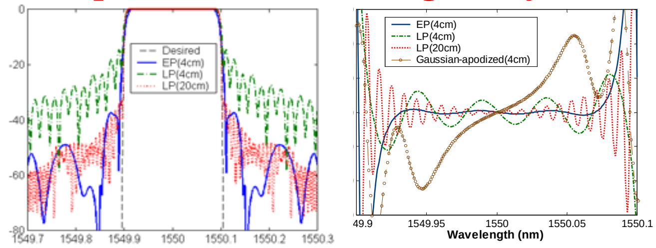
Advanced FBG design and fabrication



Fabricated Dispersionless FBG



Dispersionless FBG designed by EP



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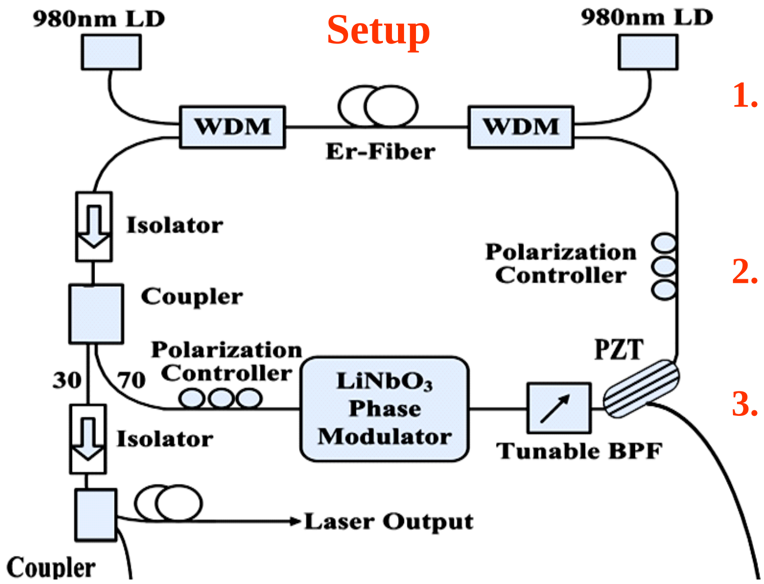
Modelocked Fiber Soliton Laser



Features:

1. 10-40GHz, 500-800fs <u>directly from the laser</u>.
2. Active harmonic modelocking +Passive P-APM.
3. Asynchronous and Bound soliton

Prof. Y. Lai

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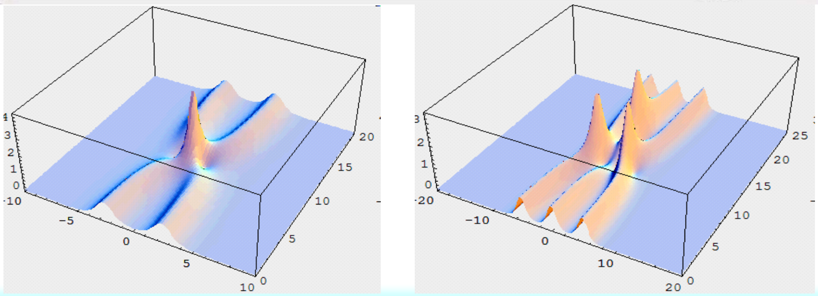
Proof of Quantum Entanglement

We rigorously prove that the time-multiplexed optical solitons become quantum entangled in the sense that their "quadrature components of internal modes" satisfy the EPR non-local criterion: the uncertainty product of the inferred quadrature components is below the Heisenberg uncertainty product limit.

$$\text{Squeezing ratio of } \mathrm{Var}[\hat{q}_1 + \hat{q}_2]\,\mathrm{Var}[\hat{p}_1 - \hat{p}_2] \le \frac{\lambda_{opt}}{\lambda_{snd}} < 1$$



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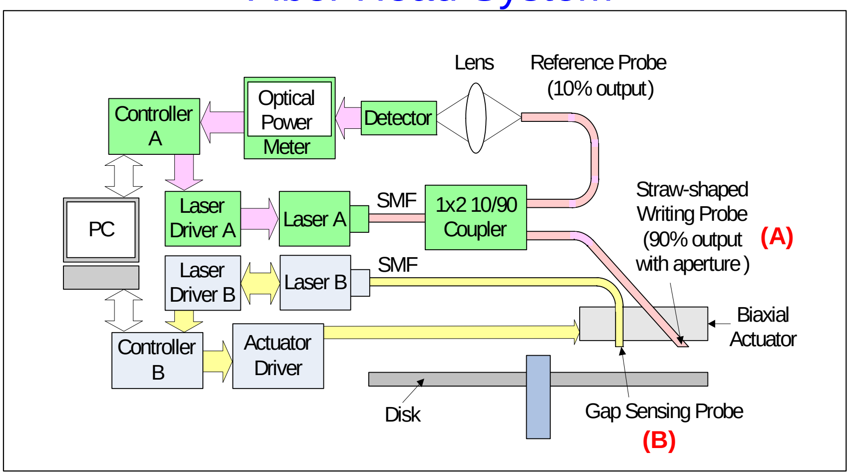
Dual-probe Integrated Near-Field Fiber Head System



A. Writing probe: high transmission through a nanoaperture by hybrid resonant effect.
B. Servo probe: air gap as an external cavity modulation to obtain positioning signal.

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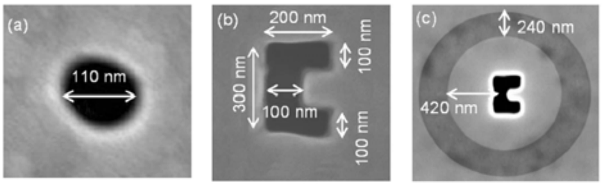
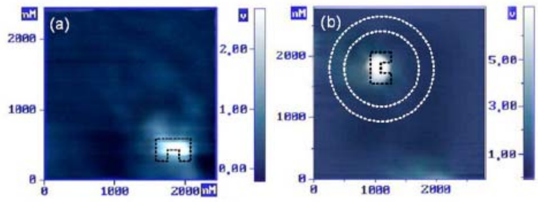
Nano-Aperture: Free Standing Near-Field Measurement



(a) Circular　(b) C-shaped　(c) C-shaped with corrugation

PT*: near-field power throughput relative to circular aperture



(a) NF image of C-shaped (PT* = 149X)　(b) NF image of C-shaped with corrugation (PT* = 332X)

Optics Letters, …

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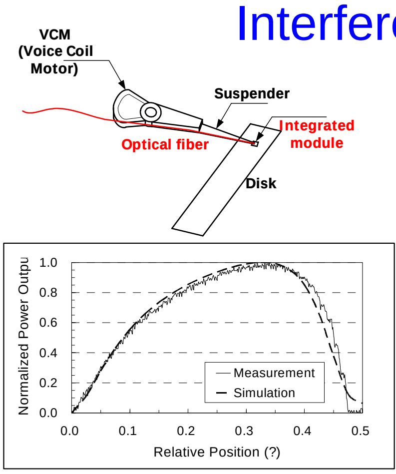
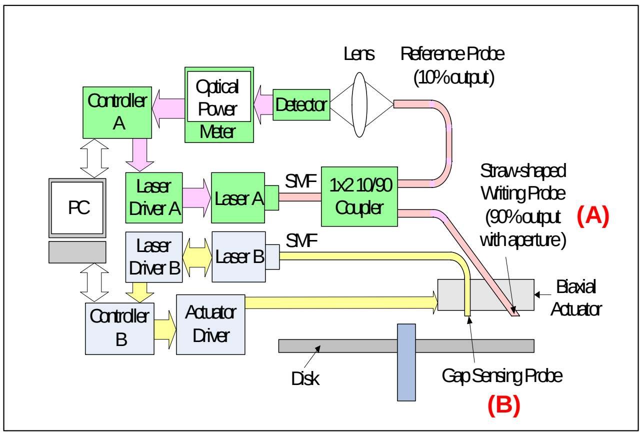
國科會 建構兆位元紀元的光電科技(II)
Photonic Science and Technology for Tera Era (II)

Active Gap Servo by Self-mixing Interferometric Feedback





- **Self-mixing interferometric signal used as feedback signal**
- **Laser sensor installed on bi-axial actuator**
- **Controlling system designed for gap servo**

JLT, …

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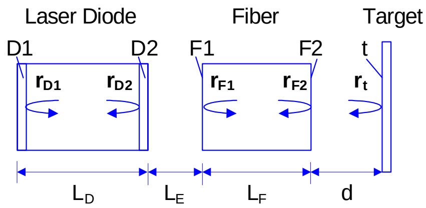
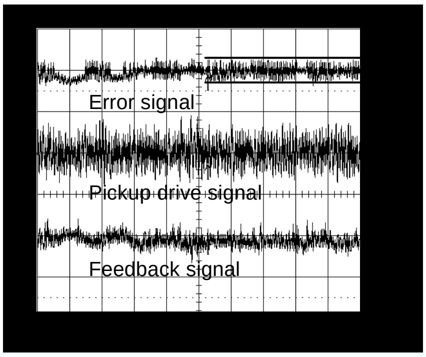
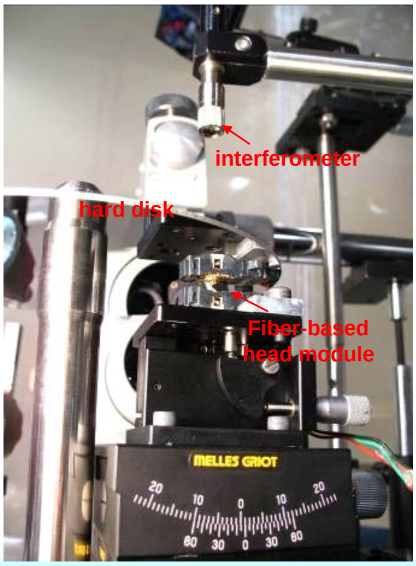
國科會 建構兆位元紀元的光電科技(II)
Photonic Science and Technology for Tera Era (II)

Near-Field Servo Control for Nanoscaled Position







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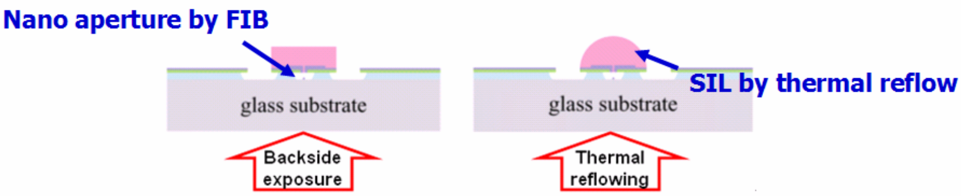
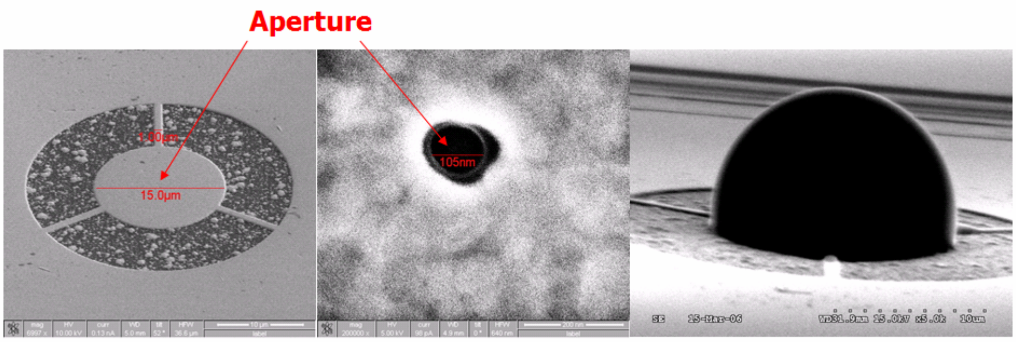
Photonic Technology

Self-Alignment of 15 um SIL and 100 nm aperture with supporting arm structure





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X. APPENDIX V: FINAL SELF-ASSESSMENT

PROGRAM TITLE: 子計畫二：下世代光通訊與儲存

Subproject 2 : Next Generation Optical Communication and Optical Storage Technologies

	Assessment Subject	Score（1~5, Low to High）
Program's Contents & Performance	Importance & Innovation of the Program's Major Tasks	5
	Clarity and Presentation of the Report	5
	Viability of the Program's Approaches & Methodologies	5
	Principal Investigator's Competence for Leading the Program	4.5
	Interface & Integration between Overall & Sub-Project(s)	4
	Interface & Integration among All Sub-Projects	4
	Manpower & Expenditures	4.5
Program's Results	Contribution in Enhancing the Institute's International Academic Standing	4.5
	Impact on Advancing Teaching or on Technology Development	4.5
Total Score		**41**

REVIEWER'S COMMENTS & SUGGESTION:

This is the summary of six viewers' comments and suggestions.

1. Overall the research direction and technical capabilities resulting from this project on optical communications and optical storage are excellent. Publication activity is high.

2. The research on the hybrid wireless/fiber access network might look at the pioneer worker, Prof. GK Chang of Georgia Tech, and made a comparison.

3. Based on the well established infrastructure and capability for research, to develop closer interactions with some internationally leading groups in the same research areas to gain more international reputation are suggested.

4. Further close interactions with key industrial partners in Taiwan to enhance the technical impact is also expected.

5. The potential applications of MEMS-based devices are suggested.

Program Reviewer's Signature: Cheng-Chung Lee 2008/05/30

REPLY TO REVIEWER'S COMMENTS & SUGGESTION:

C1. Overall the research direction and technical capabilities resulting from this project on optical communications and optical storage are excellent. Publication activity is high.

A1. We thank the reviewers for appreciating our efforts and achievements.

C2. The research on the hybrid wireless/fiber access network might look at the pioneer worker, Prof. GK Chang of Georgia Tech, and made a comparison.

A2. Actually Prof. G.K. Chang of Georgia Tech in USA has been one of our international cooperators already. One of our Ph.D graduates is now working as a postdoc with Prof. G.K. Chang on advanced optical transmission studies like the bidirectional fiber transmission systems. The frequency doubling/quadrupling techniques for generating Radio-Over-Fiber (ROF) signals is our unique approach which makes us presently in the leading position among all the research groups in the world.

C3. Based on the well established infrastructure and capability for research, to develop closer interactions with some internationally leading groups in the same research areas to gain more international reputation are suggested.

A3. The suggestion is definitely the direction we need to pursue more. Presently we have had successful cooperation with famous international groups like Prof. G.K. Chang of Georgia Tech in USA, Prof. Y.J. (Ray) Chen of UMBC in USA, and Prof. Ed. Schlesinger of Carnegie Mellon University in USA. We shall try to explore more possibilities along this direction in the future.

C4. Further close interactions with key industrial partners in Taiwan to enhance the technical impact is also expected.

A4. The suggestion is also one of the directions we need to pursue more. Currently Corning in Taiwan has been very interested in our ROF techniques. Local industrial companies on 60GHz wireless systems may also be of interest. Local industrial companies on optical storage may also be of interest to our near-field optical storage techniques.

C5. The potential applications of MEMS-based devices are suggested.

A5. In terms of the high resolution and speed of the future optical storage system, miniaturization is certainly a concerned drive for further realization. We think some important potential applications of MEMS-based devices for storage will be: (1) SIL/nanoaperture integration for near-field optical systems; (2) MEMS-based integration of optical elements with the magnetic head used in heat-assisted magnetic recording. We shall try to explore more along these directions in the future.