Chapter 7

Summary

7.1 Summary and Prospect

Here we have presented the developing and applicability of important semiconductor optoelectronic devices, transmissible SESAMs or SESAs, for 1.3-μm passively pulsed laser. InAs/GaAs QD were first used as a low-loss (2.0%) SESAM for PQS and CML of a Nd-doped laser operating at 1342 nm. Although the InAs/GaAs QD SESAM was remarkable for CML, it was not suitable for PQS due to its shallow modulation depth. So we demonstrate the first use of InGaAsP QW as a saturable absorber in the Q-switching of a diode pumped Nd-doped 1342-nm laser. The present result indicates the possibility of using InGaAsP QW/barrier structure to generate a PQS 1.3-μm laser with peak power greater than 1 kW.

Another important optoelectronic technology called VECSEL was also presented. We bring up a room-temperature high-peak-power AlGaInAs 1.36-μm TEM_{00} laser pumped by a diode pumped AQS Nd:YAG 1.06-μm laser. The present result indicates the possibility of using this configuration to generate a room-temperature high-peak-power pulse laser at different wavelength including the wavelength that can not be generated before. For further study, the modification of mechanics in low-temperature system for VECSEL is under way. In the future, we also want to study CW VECSEL techniques including RGB light source. At the same time, the research on AlGaInAs QW wafers as a SESA for diode-pumped PQS solid-state laser will be finished soon.

More phenomena were observed during the experiments of these semiconductor devices. Two of the most interesting topics were Rabi oscillation and long-range phenomenon. Rabi oscillation appeared on pulse shape is the result of strong coupling from two or more oscillators. Under certain condition, strong oscillation with different Rabi frequency could be obtained. To analyze and reveal mechanism behind the fast, deep, regular (or sometimes irregular) oscillation is a way to clear the dynamics of the two-level coupling in semiconductor laser and PQS laser with SESAM. On the other hand, the experimental result might be helpful on theoretical discovery of Rabi oscillation. Long-range phenomenon we discovered in the beginning was the narrow-band fluorescence on defects that was far from the pump spot about several millimeters. L. V. Butov's group and D. Snoke's group are endeavoring to study the phenomenon of long-range transport and cold exiton in QW structure under low-temperature condition from 2002 [1-6]. Yamamatsu's group is talking about polariton lasing recently [7,8]. Through spatial resolved spectrum and image analysis, we find something interesting and partly similar to their study. The most difference is that we do not need cooling QW in low-temperature system and we can see more obvious evidence.

In part B, the spatial structure of 2D disorder wave functions with weak localization has been explored with the conical SHG of laser in random domain structures. The statistics of the experimental near-field patterns agree with the theoretical distributions with the correction of weak localization. Compare to eigenfunctions of chaotic billiard and integrable rectangle with IPR of 2.25 and 3 [9], wave functions of experimental ridge patterns were with IPR of 4.2-5.8. More importantly, the analysis of the intensity correlation, ICF, reveals that the localization effects significantly enhance the magnitude of the long-range correlation. The present result also confirms the possibility of using conical SHG as a diagnostic tool for topographical characterization of crystals in which localization phenomenon occurs naturally. Research on disordered observable measurement in spatial/time domain, pattern formation and birefringence through all kinds of near-field patterns and their corresponded far-field patterns would be continued. The research includes the theoretical simulation and the study of experimental results in different material and even different laser system.

For modern military requirement, we have presented a compact efficient 1573-nm passive pulse laser with a pulse energy of 3.3 mJ. The eye-safe laser employed a diode-pumped passively Q-switched Nd:YAG laser to pump an intracavity OPO in a shared cavity configuration. A lens duct has been designed to efficiently couple the pump radiation from the diode stack into the laser crystal. The effective conversion efficiency with respective to the optimized 1064-nm Q-switched pulse energy was as high as 51%. Finally the target might be >10-mJ and >1-MW eye-safe laser operated under broad environment temperature. In addition to IOPO with Nd:YAG/Cr:YAG, other approaches such as intracavity SRS, IOPO with Nd:YVO_4/SESA, and Er/Yb codoped fiber laser would be thought over. Also for military requirement, we are establishing experiments of fiber laser, a booming category of solid-state laser. High-power diode-pumped rare-earth-doped double-clad fiber lasers have been promised as efficient and compact light sources on the grounds of excellent beam quality, high efficiency, and broad tuning ranges [10,11]. Besides the powerful applicability on industry and military, there are many nonlinear effects and laser technologies need to be studied.

At last, we have studied of Nd:YVO_4 intracavity self-Raman laser and the solution to improve damage threshold. With an undoped YVO_4 crystal as a Raman shifter, we substantially improve the reliability and the output performance of AQS 1176-nm Nd:YVO_4 Raman laser. With an incident pump power of 18.7 W, the average power is greater than 2.6 W at 80 kHz. With an incident pump power of 12.7 W, the pulse energy and peak power is higher than 43 μJ and 14 kW at 40 kHz. The successful power scale-up could also be used for other Nd-doped Raman lasers at other wavelength. Following that, we have demonstrated a Nd:YAG/$BaWO_4$ Raman laser with high efficiency by the first use of actively Q-switching. With an incident pump power of 9.2 W, as much as 1.56 W of average power at the Stokes wavelength was generated at a pulse repetition rate of 20 kHz, corresponding to an optical-to-optical conversion efficiency of 16.9%. The effect of self-focusing-induced damage is a critical issue for the power scale-up of intracavity SRS.

7.2 Fortuitous Coincidence?

Overview of the physics and technologies researched in these three years are talking about: 1. photon, electron, phonon, and defect; 2. period world tie in quantum mechanics and superposition; 3. coherence; and combination or nonlinear interaction of all of them. I was slightly surprised to the coincidence that each phenomenon can appear in various systems. Although the realized results we presented here can not give a complete picture about those physics yet, the results imply that the laser systems would provide not only its lasing but also its creditable intracavity environment for development of science and technology. Again, what the author have presented here is the research on intracavity nonlinear interactions of laser light and matter, from studying existing feasible laser systems and nonlinear effects to be the groundwork of thorough understanding hereafter.