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Book reviews

Tunable Solid State Lasers

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[pp. i–viii + 203, with 147 Figs.]

This book includes proceedings of the First International Conference in Tunable Solid Statd Lasers held at La Jolla Institute, Calif., USA, in June 1984. So, we can observe a renewey interest in solid state lasers. It is mainly stimulated by a will to obtain compact primare laser sources tunable throughout the visible and near infrared spectral regions. The organizers of this conference invited theoretical and experimental investigators, crystal growers and laser device engineers. Though the conference has in its headline an adjective "international" there are only three foreign papers and there are no papers dealing with Japanese or Soviet investigations. Nevertheless, all the twenty four published papers divided into four basic topics provide an interesting overview of major achievements, discoveries and development in the field of solid state visible and IR vibronic lasers.

Single crystals doped with transition metal ions have proved their ability to be used as laser materials for laser systems tunable in the infra-red and visible spectral regions. The lasers operated on such materials are usually called vibronic.

In the first part of the book, entitled *Operational vibronic lasers. Advanced design and applications* seven papers are presented, devoted to the latest investigations and prospects of vibronic lasers as well as applications of these lasers, particularly to lidar systems.

An experimental description of two broadly tunable lasers $Co:MgF_2$ (1.5–2.3 μm) and $Ti:Al_2O_3$ (0.66–0.99 μm) is given by P. F. MOULTON. $Co:MgF_2$ laser operated at liquid nitrogen temperature gave the 60–110 mJ pulse energy with the 1 ms pulsewidth. Laser was pumped by a cw or pulsed Nd laser. The Q-switching regime results are presented. $Ti\text{-}Al_2O_3$ laser is one of the newest solid state tunable lasers. Apart from pulse operation this laser can operate continuously with liquid-nitrogen cooling and pumping with an argon-ion laser. An interesting conclusion is that cw operation of this laser should be possible at room temperature. It is a promising laser, particularly with the new host crystals.

G. HUBER and K. PETERMANN give review of results obtained for Cr^{3+} doped crystals which are favourable candidates for room-temperature lasers with high quantum efficiency in the red and near infra-red speectral regions. They present spectroscopic and lasing parameters for different host crystals (garnets and tungstates) for Cr^{3+}. Tunable cw output up to 200 mW achieved in Cr : GSGG laser seems to be promising.

A useful analysis of lasing properties of different transition metal ions Cr^{3+}, Co^{2+}, Ni^{2+}, and V^{2+} doped in cubic perovskites is made by U. DÜRR et al. They formulated requirements for vibronic lasers and host materials and presented spectral ranges of emission for different transition metal ions in cubic pervoskites which generally covered the spectral region between 0.7–2 μm. Up till now, however, none of these lasing transitions have manifested operation at room temperature.

$BeAl_2O_4 : Cr^{3+}$ (alexandrite) has turned out the most successful tunable solid state laser material. The construction and parameters of high repetition, high power, line-narrowed alexandrite laser is presented by R. C. Sam et al. The system consists of a master oscillator (1 rod of 10 cm length) and an injection-locked oscillator (3 rods). When pumped by xenon flashlamps the system gives 600 mJ of energy in pulse of temporal pulsewidth 300 ns with repetition to 250 Hz. The narrowing of the laser output linewidth is obtained by using special birefringent filter. This laser which can operate in the range of 790–793 μm is very useful for lidar applications. Numerous technological problems and difficulties are considered in this paper.

F. Allario and B. A. Conway give a broad overview of NASA's needs for Lidar System Technology applied to space, airborne and groundbased platforms. Tunable solid state lasers are particularly prospective as laser transmitters for measuring atmospheric aerosols, meteorological variables and atmospheric species. The authors present requirements concerning tunable solid state lasers as well as NASA's fundamental and applied research programs in this field.

A description of construction and parameters of transmitters for a meteorological lidar based on a narrow-band tunable alexandrite laser is given by F. P. Roullard. A fully automatic system equipped with the spectrometer, telescope and computerized data acquisition modules makes it possible to measure humidity, aerosols, extinction coefficient, pressure and temperature. The narrow-band operation is secured due to three systems of tuning elements: birefringent filter, tilt tuned etalon, and piezoelectrically tuned etalon. The spectrum analyzer of the laser beam consists of 1024-element photodiode array connected with a system of signal processing.

The second part of the book entitled *Vibronic laser materials spectroscopy* includes six papers devoted to the recent results on the spectroscopy of transition metal ions for tunable solid state lasers. Materials which exhibit strong absorption bands and broad band vibronic emission are of special importance for development of lasers whose wavelength can be tuned continuously over a wide spectral range. Hence, the investigation can be performed in two directions: either to find new vibronic laser materials and or to improve the existing vibronic laser materials.

R. C. Powell gives a survey of spectroscopic properties of 4d and 5d transition metal ions in different types of host crystals (the currently operating vibronic lasers are based on 3d transition metal ions such as Cr^{3+}, Ti^{3+}, Co^{2+}, and Ni^{2+} in various types of host crystals). He presents also the four-wave mixing spectroscopy which has been used for investigation on an alexandrite crystal.

L. Esterowitz et al. inform about the first $Ti : Al_2O_3$ laser under flash-pumped excitation. The spectroscopic investigations on trivalent cerium doped Cr^{3+} in such host materials as YAG, CaF_2, $LiYF_4$ are reported by D. S. Hamilton. Cuprous ion doped crystals and glasses are considered by L. G. De Shazer.

The third part of the book, entitled *Vibronic laser material growth* contains five papers. It is a rich overview of crystal growth techniques suitable for material preparation. The optimum operation of laser materials depends on a number of important crystal growth parameters. That is why this subject was particularly emphasized at the conference. A large number of transition metals and host materials giving a laser action require well developed growth techniques because this domain seems to limit the rate of investigation on vibronic lasers.

An overview of growth processes for oxide materials is presented by G. M. Loiacono. He estimated the usefulness of the basic growth methods such as: Bridgman method (very good for rapid preparation of spectroscopic study samples), heat exchanger method (ideal for large scale and low-cost production of a number of materials), and Czochralski method (particularly useful for high optical quality crystals suitable for laser operation). He discusses the critical material parameters such as dopant distribution, crystallographic orientation and optical quality.

The description of the growth of high melting point oxide crystals by the Czochralski method as well as a general approach to crystal growth including crucible material selection, atmosphere control and fluid dynamics consideration are given by M. R. KOKTA. In this paper one can find vast practical information about crystal growth parameters and the scaling of crystal sizes.

The heat exchanger method was used by F. SCHMID and C. P. KHATTAK for the growth of high quality Co : MgF_2 and Ti : Al_2O_3 crystals up to 6.5 cm in diameter; these are the largest sizes ever grown in these materials. Both these products were successfully tested as laser materials.

R. S. FEIGELSON proposes the new permissible method of growth of crystals based on laser heating. This method called the laser-heated pedestal growth was successfully used for the growth of fiber crystals. The 50 Watt CO_2 laser was split into two or more beams which are focused onto the end of a source rod containing the desired compound and dopant. This system can be very effective because of a high speed. Oxides and fluorides absorb 10.6 μm radiation efficiently. Hence, the system does not need a high power CO_2 laser – it can be of less than 50 W. The application of video tapes permits one to control in real time the growth phenomena such as evaluation of changes in the zone and interface shape, defect formation, melt convection and the size. This method seems to be very prospective for production of vibronic materials.

The last part of the book – *Vibronic laser theory and cross-fertilization through interdisciplinary fields* – includes five papers. R. ORBACH summarizes the major aspects of excitation transfer processes relevant to the vibronic materials. He outlined basic factors and various excitation processes which play a dominant role in excitation transfer between ions in vibronic materials.

R. H. BERTRAM considers the effect of thermal quenching of fluorescence in chromium complexes in solids. This effect limits the tunability of lasers based on these materials.

Theoretical methods for the study of Cu^+ ions in alkali halides (NaF and NaCl) are given in two papers (N. N. WINTER and R. M. PITZER, D. S. MCCLURE).

The electron-phonon coupling and defect processes in vibronic materials as underlying mechanisms of the tunable laser operation are considered by A. M. STONEHAM.

S. C. RAND and L. G. DESHAZER report on the first laser action at 540 nm from green diamond at room-temperature.

It should be noted that the reader interested in the above mentioned field can find an excellent introduction to the physics of laser crystal in the book written by A. A. KAMINSKII and entitled *Laser Crystals* (Springer Series in Optical Sciences, Vol. 14, Ed. Springer-Verlag, 1981).

Studying the proceedings of this conference one can realize how important and necessary is a close cooperation and communication between theoretical and experimental investigators for discoveries and development of materials for laser application.

Summing up, these well selected materials give a broad overview of current investigation, problems and difficulties in the tunable solid state lasers. One can hope that next conferences will present permanent progress in this field and form a useful basis of information about this field if their proceedings are published in the same way.

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