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Recent Advances in Laser Devices*

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This talk discusses some of the recent advances at M.I.T. Lincoln Laboratory in the area of tunable semiconductor diode lasers (including lead-salt diode lasers as well as GaInAsP/InP and GaAs external cavity controlled lasers), miniature Nd-compound lasers, and submillimeter Schottky detectors.

Semiconductor Lasers

Extensive use of tunable lead-salt semiconductor diode lasers has been made for high-resolution spectroscopy in the past and much effort has been devoted to improving the reliability, output power, and mode quality of these devices. Double heterostructure PbSnTe diode lasers have been fabricated[1] that operate continuously at temperatures up to 120 K with single-frequency output powers of a few hundred microwatts at 80 K at a wavelength near 10 μm, which is more than adequate for linear absorption spectroscopy. Distributed feedback PbSnTe diode lasers have also been fabricated which operate continuously near liquid helium temperature. Most of the output from these devices occurs at a single wavelength with a continuous tuning range of several cm^{-1} that is obtained by varying the injection current.

The quaternary system GaInAsP/InP has been used to fabricate double heterostructure, stripe geometry diode laser devices that operate continuously with single spatial mode single-ended output powers of more than 10 mW at room temperature and 50 mW at liquid nitrogen temperature. Some of these devices have exceeded 6000 hours of continuous operation at room temperature[2] so far without failure or substantial degradation of output. In addition to their application for fiber optical communications, such devices are useful for spectroscopy. In order to understand the gain broadening mechanisms and to improve the spectral output characteristics of GaInAsP/InP and GaAs lasers, they have been operated with external cavities. Results for frequency-controlled devices will be presented.

Miniature Rare-Earth Compound Lasers

Stoichiometric compound rare-earth crystals such as neodymium pentaphosphate (NdP_5O_{14}) have the advantage of maintaining a high fluorescence lifetime and efficiency at high rare-earth ion densities (10^{21} to 10^{22} ions/cm^3). Such crystals have been operated as optically pumped miniature lasers by using a cw dye laser, AlGaAs diode lasers, and miniature xenon flashlamps. The partial substitution of optically inert rare-earth ions such as lanthanum does not affect the properties of the active rare-earth ions and allows the tailoring of the fluorescence properties to fabricate specific laser devices. Such devices would be particularly scalable in the output power range between semiconductor diode lasers (~ 10 mW) and Nd:YAG lasers (~ 1 W) with overall power conversion efficiencies of a few percent. The broad gain-bandwidths (> 50 cm^{-1}), low material dispersion, and small cavity lengths make these devices possibly more attractive for mode-locking in the 1-10 GHz range than either semiconductor lasers or Nd:YAG lasers.

A continuous output power of 50 mW at 90% quantum efficiency has been achieved[3] from a crystal volume 100 x 100 x 100 μm of NdP_5O_{14} using a 0.58 μm dye laser pump. This scheme was also used to intercavity frequency double[4] using a barium sodium niobate crystal to produce a 1 mW cw output in the green. More recently,[5] a miniature xenon flashlamp has been used to excite a 1 x 1 x 7 mm NdP_5O_{14} crystal to produce several millijoules of multimode output with only one joule of energy into the lamp. One millijoule was also obtained in a 5 nsec pulse using an intercavity saturable dye Q-switch.

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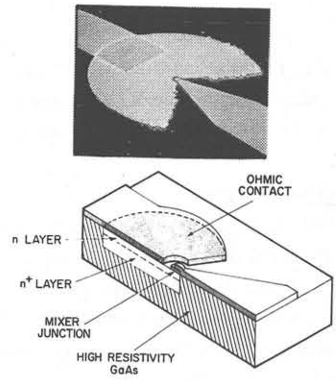
Schottky Detectors

Substantial progress has been made in the development of Schottky barrier heterodyne detectors for submillimeter radiation. Such detectors operate at room temperature and can detect submillimeter radiation with high sensitivity. The newest Schottky detectors are fabricated on a GaAs planar structure using photolithographic techniques. Diodes of Pt/GaAs have been fabricated with diameters of 2 μm along with matched strip-line antennas and IF filter networks. Heterodyne detection has been observed using such a detector at an IF frequency of 90 MHz, between the 10th harmonic of a 76.16 GHz klystron signal and a formic acid optically pumped laser at 393.6 μm. Heterodyne detection of submillimeter laser radiation has also been observed at extremely high harmonics (81^{st} harmonic of an X-band source) demonstrating the capability of these diodes. Figure 1 shows the schematic arrangement and fabrication details for one of these devices. Sensitivities for such detectors is better than 10^{-18} W in the heterodyne mode. Extension of the fabrication techniques for these devices could produce response at significantly shorter wavelengths as well as phased-array operation for broad area detection.



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References

1. J. N. Walpole, A. R. Calawa, T. C. Harman, and S. H. Groves, Appl. Phys. Lett. 28, 552 (1976).
2. J. J. Hsieh and C. C. Shen, Fiber and Integrated Optics (to be published).
3. S. R. Chinn, J. W. Pierce, and H. Heckscher, Appl. Optics 15, 1444 (1976).
4. S. R. Chinn, Appl. Phys. Lett. 29, 176 (1976).
5. S. R. Chinn and W. K. Zwicker, Appl. Phys. Lett. (to be published).
6. R. A. Murphy, C. O. Bozler, C. D. Parker, H. R. Fetterman, P. E. Tannenwald, B. J. Clifton, J. P. Donnelly, and W. T. Lindley, IEEE Transactions on Microwave Theory and Techniques, MTT 25, 494 (1977).