Characteristics of Mode-Coupled Lasers

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Experimental studies of lasers with mode coupling will be described. Forced mode coupling was achieved through the use of an ultrasonic diffraction grating placed inside the cavity as described by Hargrove, et al.* Experimental data was obtained with He-Ne and argon lasers whose axial mode spacing was equal to 100 Mc.

When sufficient mode coupling is introduced into the cavity, the laser output consists of a periodic train of subnanosecond width pulses without an appreciable reduction in average output power. The ratio of peak power with mode coupling to the average power is approximately equal to the number of coupled modes. A typical number of 20 coupled modes results in a peak power of 20 times the average power. The theoretical pulse width was approximately 10 nanoseconds divided by the number of coupled modes. Pulse widths of $\sim$ 0.5 nanoseconds have been observed with a high-speed photomultiplier consistent with theory.

In addition, it was observed that mode coupling can occur naturally in a laser without the use of the internal modulator. The experimental conditions necessary for obtaining a self-pulsing laser will be discussed. A theoretical explanation, based upon some preliminary experiments, will be described.

*L. E. Hargrove, R. L. Fork, and M. A. Pollack, "Locking of He-Ne Laser Modes Induced by Synchronous Intracavity Modulation," Applied Physics Letters, July 1, 1964.

Laser Frequency Translation by Means of Electro-Optic Coupling Control

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One of the limiting technologies affecting the utilization of lasers is the problem of efficient modulation of laser radiation. Most optical modulators have some or all of the following defects: They require a substantial amount of drive power; they have very small modulation depths; or they produce undesired sidebands in addition to the modulation of interest. We have built and tested a single-sideband modulator which overcomes these difficulties.

We have placed an electro-optic modulator in a laser cavity in such a way as to couple out all the available laser power and translate its frequency. Modulators can be made for frequencies from 30 Mc to 10 Gc, with bandwidths of as much as 100 Mc in the latter case. A KDP modulator can be placed within a laser cavity to produce polarization modulation which can then be coupled out by means of the polarizing optics or the Brewster angle windows[1]. A 3 Gc single-sideband suppressed-carrier modulator making use of this selective coupling is described. The cavity-type KDP modulator is placed in the laser cavity with the electrically induced axes of the KDP at 45° to the direction of polarization of the laser oscillation. In modulators described earlier[2], a birefringent plate was necessary to permit sideband suppression. In this internal modulator, we make use of the natural birefringence of the KDP to allow us to omit the birefringent plate. Thus we have a means for shifting the frequency of a laser without sacrificing any of the potentially available laser power. As compared with external modulators, the incorporation of the single-sideband modulator into the laser cavity gives almost a hundredfold increase in the amount of frequency shifted power that can be obtained from a given laser, as a function of modulation power.

[1]K. Gurs and R. Muller, "Internal Modulation of Optical Masers," Proceedings of the Symposium on Optical Masers, Polytechnic Press, 1963, pp. 243-252.

[2]Russell Targ, "Optical Heterodyne Detection of Microwave-Modulated Light," Proc. IEEE (Correspondence), Vol. 52, pp. 303-304, March 1964.

Microwave Modulation of a Ruby Laser Output by Absorption

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Ruby exhibits the Zeeman effect in the energy levels responsible for the absorption of the R_1 line. When a ruby laser is directed to pass through a section of unexcited ruby rod, the intensity of the transmitted beam is strongly dependent upon the magnetic field applied to the absorber. This effect was used to modulate the amplitude of a pulsed ruby laser in the microwave frequency region. The experimental modulator consisted of a 0.2 inch long ruby absorber located at one end of an S-band TE_{111} mode cylindrical cavity pumped by a 3.2 Gc microwave source. A d. c. bias magnetic field was also applied to the absorber. When both the laser and the absorber rods were cooled to 80° K, the modulated beam attained maximum modulation index with a bias field of 2.5 kOe. This and other experimental results agree well with calculations made from a small-signal analysis of this modulation technique, and indicate that the various known relaxation mechanisms in the spin system of ruby do not impose a frequency limit to this method of modulation. Comparison between this technique and other conventional methods, as well as criteria for achieving high modulation efficiency, will be discussed in light of the small-signal analysis.

Silicon p-n Junctions as Detectors for uv Radiation

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Photoconductive and photovoltaic devices for detection of short wavelength visible and ultraviolet radiation have not previously been developed to the same extent as solid state infrared detectors. The spectral response of semiconductor devices generally exhibits a sharp drop in sensitivity with decreasing wavelength e. g. in standard Si devices, the $D^*\lambda$ at 4000 Å is lower than the $D^*\lambda$ at 8000 Å by orders of magnitude and is dropping rapidly as one proceeds into the ultraviolet.

In this paper we discuss the preparation and properties of silicon p-n junction devices having high sensitivity in the region 2000–4000 Å. Response of these devices has, in fact, been observed in the far uv at wavelengths as low as 584 Å. The far uv behavior will be reported in another communication. The $D^*\lambda$ at 8000 Å of such devices was measured at 5×10^{11} cm cps$^{1/2}$/watt; the ultraviolet sensitivity at 3000 Å is down by a factor of only two from this peak $D^*\lambda$, and, in some cases, approaches this value. Models for the ultraviolet response and spectral structure will be discussed. Applications of single detectors and high density arrays of such fast ultraviolet solid state devices will be described.

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