MAGNETO-OPTIC AND ELECTRO-OPTIC MODULATORS

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An important aspect of the Faraday rotation diagnostic for tokamak plasma measurements[1,2] has been the development of suitable polarization modulators for submillimeter wavelengths. The problems are to obtain high optical transmission and fast modulation frequencies. At ORNL we have developed both a magneto-optic and an electro-optic submillimeter-wave modulators. These devices have been operated at modulation frequencies of approximately 100 kHz and both have high transmission.

The original magneto-optic modulator employed in our experiments consists of a 3-mm-thick by 1.4-cm-diam Transtech 2-111 ferrite disk mounted in the center of an air core coil.[3] The 600-turn coil produces a field of 310 g/amp and is driven by a 2.5 A-rms ac current by a 250-watt audio amplifier at a frequency of 3-5 kHz. A capacitor placed in series with the coil resonates the circuit for maximum current flow. The ferrite disk has a measured Verdet constant of 68 deg/cm-kg. With a current of 2.5 A-rms, the modulation angle is 22.3° (390 milliradians).

More recently, a new ferrite modulator has been tested which allows a much higher modulation frequency than the original device. The multi-turn coil has been replaced by a single-turn copper coil which acts as the secondary of a radio frequency transformer. A schematic diagram of the circuit is shown in Fig. 1. The primary of the modulator transformer consists of three iron-powder toroidal cores 3.2 cm i.d. x 5 cm o.d. x 1.4 cm thick. Seventy turns of #18 wire are wound on each core, and the three windings are connected in series with a 0.01-μf capacitor to achieve a resonant frequency of 124 kHz. The single-turn secondary acts as the load for the transformer.

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Low-power tests were used to determine the amplifier impedance necessary to properly match to the coil. These tests determined that a 4:1 bifilar-wound matching transformer was necessary to match the modulator to the power amplifier on the 25-ohm tap of the amplifier output transformer. With this matching transformer less than 10% of the rf power is reflected from the modulator. A photograph of the assembled modulator is shown in Fig. 2.

A laboratory set-up designed to simulate a plasma heterodyne interferometer/polarimeter experiment has been used to determine the modulator characteristics. Figure 3a displays the 800-kHz modulated carrier, the difference frequency for the two 0.447-mm (methyl iodide) laser interferometer. The spectrum is shown in Fig. 3b. The directly detected modulation signal is clearly visible at 124 kHz, as are the sidebands near the carrier. The modulation index is approximately 16%. A mechanical polarization rotator was used to simulate rotation by the plasma. The transmission of the ferrite disk was 80% at a wavelength of 0.447 mm.

We have also performed preliminary measurements on an electro-optic modulator first demonstrated by Fetterman at Lincoln Laboratory.[4] This device is a classical electro-optic modulator using a cryogenically cooled (4.2 K) $LiTaO_3$ crystal. The crystal does not transmit above 77 K. The crystal dimensions are 0.5 cm x 0.5 cm x 1 cm long with vapor deposited gold electrodes on the a,b crystallographic faces. The radiation propagates along the c-axis. As shown in Fig. 4, the crystal was oriented so that the polarization vector of the incoming radiation was parallel to a diagonal of the crystal face. The upper trace shows the effect of a 10 kV p-p 60-kHz ac modulation signal on a mechanically chopped 0.307-mm (c is 1, 2 $C_2H_2F_2$) laser. The lower trace is the applied modulating voltage. Experiments are underway to determine the electro-optic properties of the crystal over the temperature range 4.2 K to 77 K and over a range of wavelengths from 0.118 mm to 0.447 mm. When cooled to 4.2 K, the $LiTaO_3$ crystal exhibits a transmission of approximately 50% at 0.307 mm.

References

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3. C. H. Ma, D. P. Hutchinson, and K. L. Vander Sluis, Appl. Phys. Lett. 34(3), 218 (1979).

4. H. R. Fetterman, "Electro-Optic Modulator for Submillimeter Radiation," Quarterly Technical Summary Report to the Air Force Systems Command, June 26, 1975, pp. 30-31.

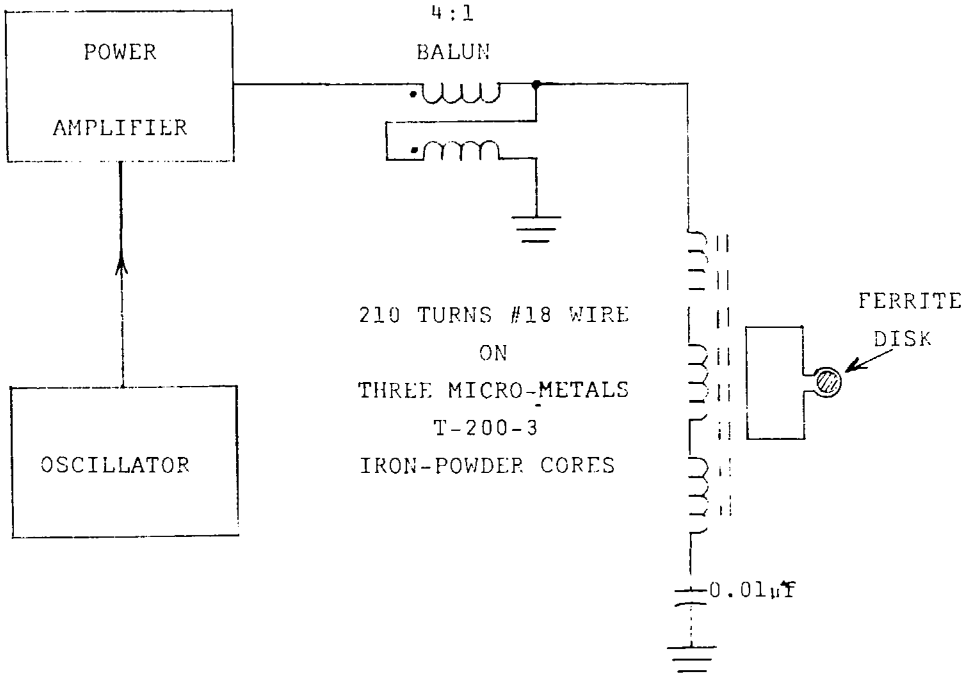

Figure 1. Schematic diagram of the ferrite modulator circuit.

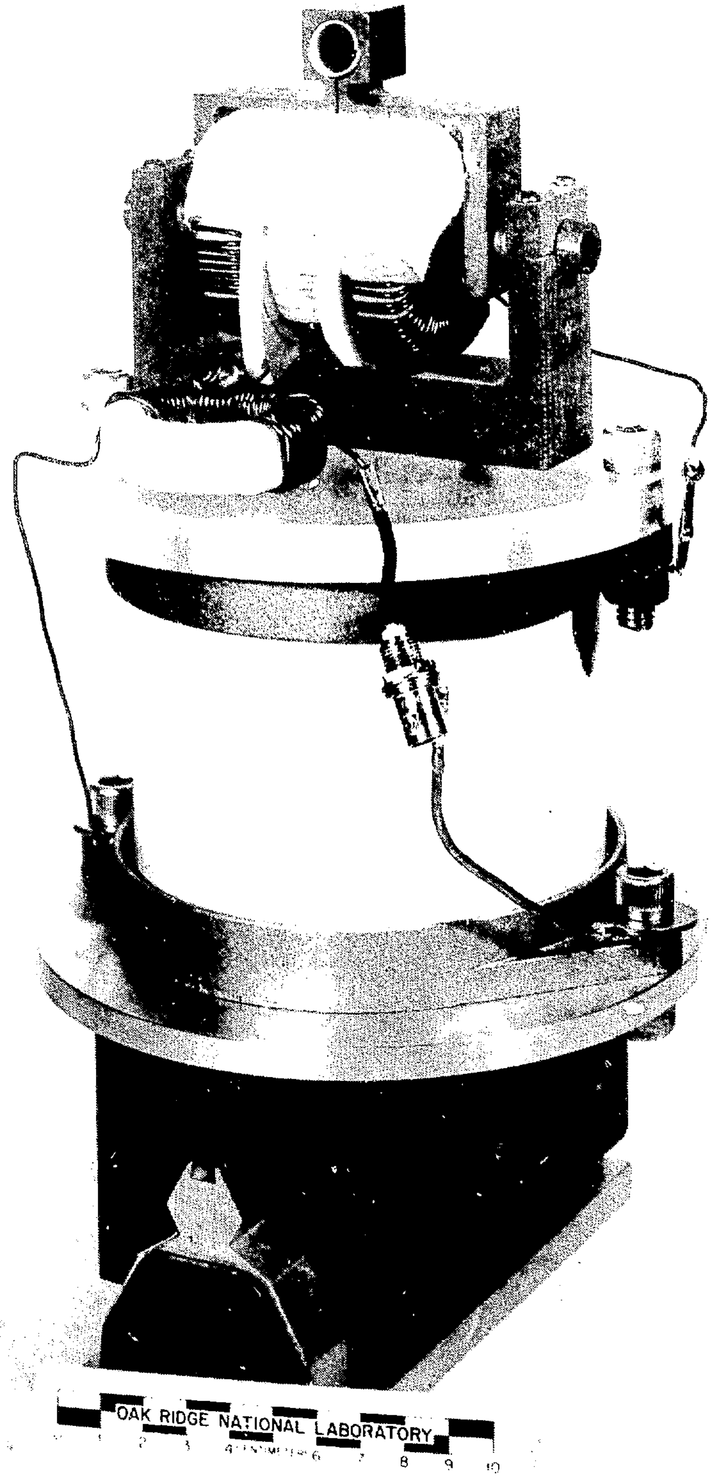

Figure 2. The modulator is constructed on an optical carrier to facilitate alignment in the optical system.

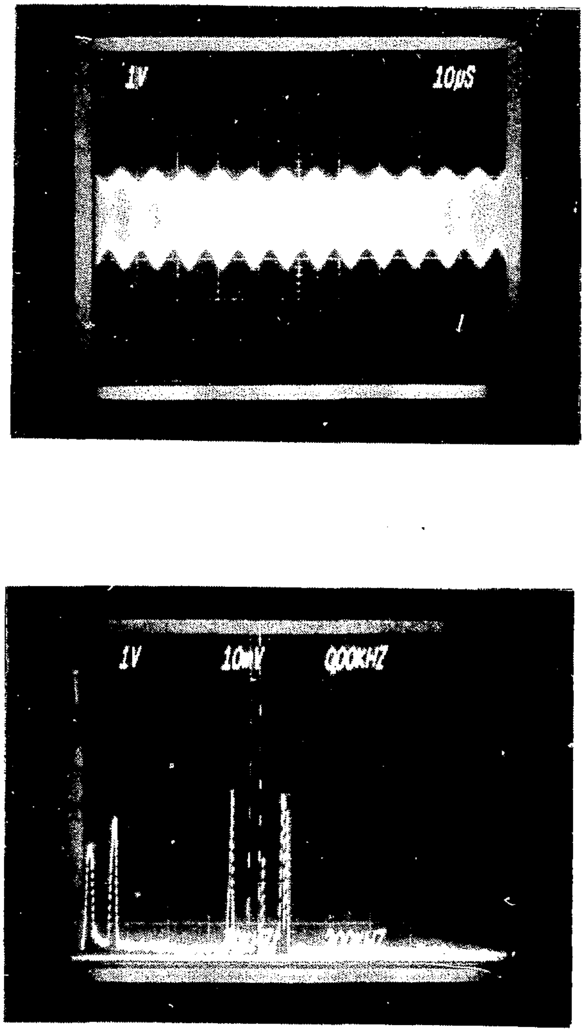

Figure 3. The upper trace depicts the modulated carrier derived from an 800 kHz beat between the two CH_3I lasers. The lower trace shows the spectrum of this waveform.

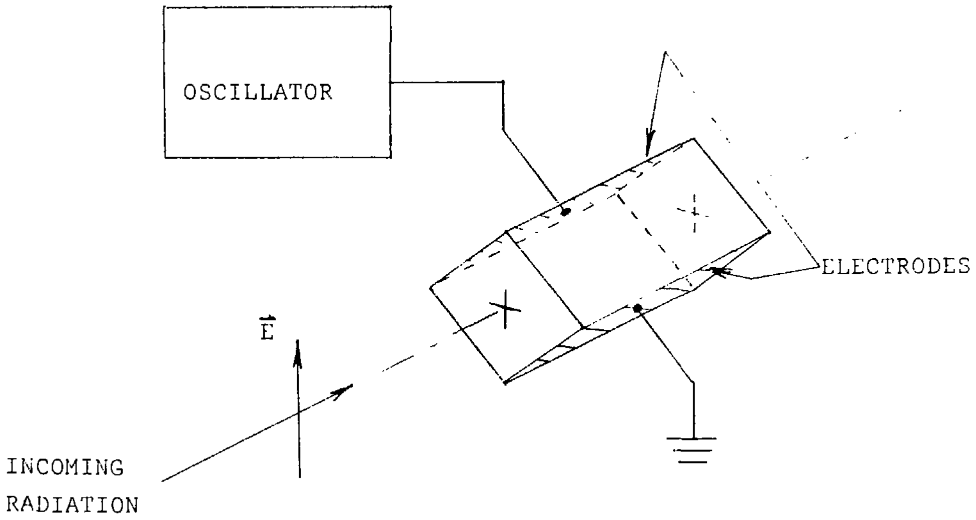

Figure 4. Orientation of the lithium tantalate crystal with respect to the incoming FIR radiation.

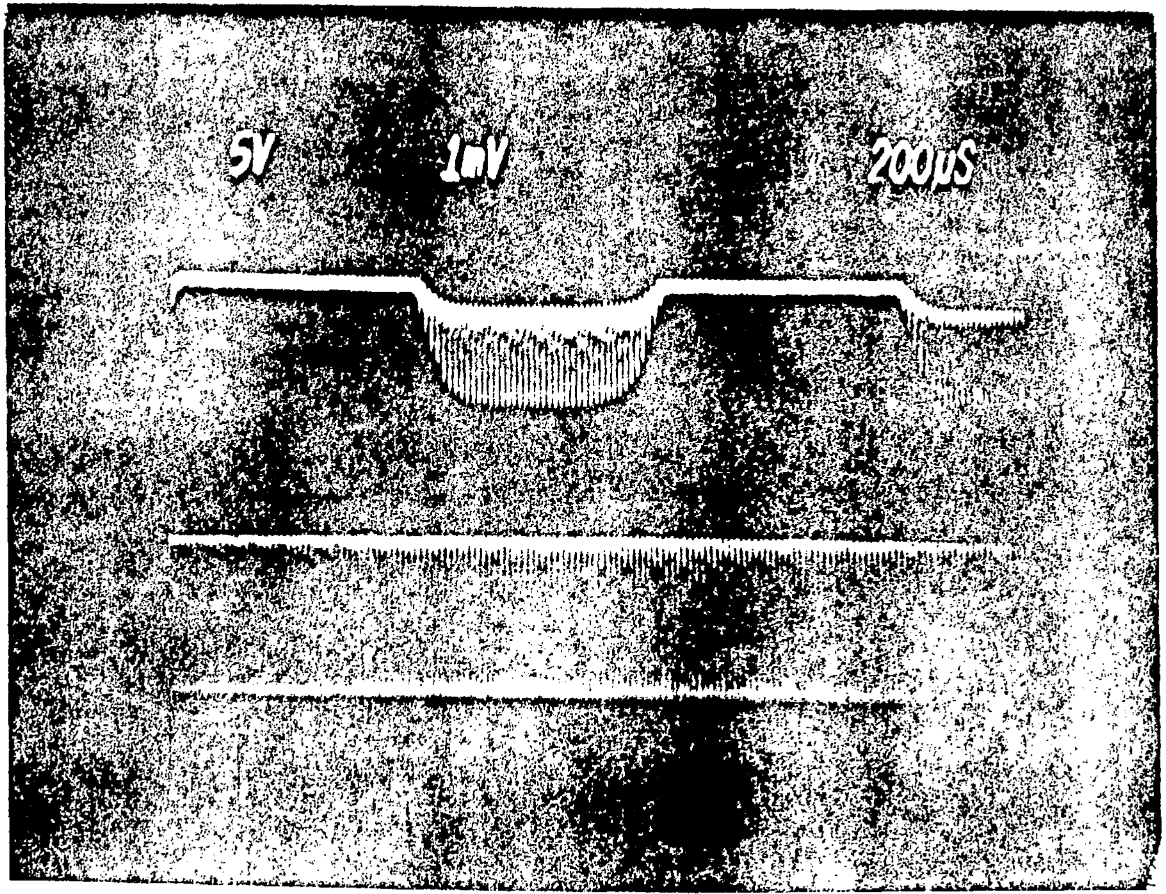

Figure 5. Nearly 100% modulation of a 0.307 mm wavelength laser has been achieved with a $LiTaO_3$ electro-optic crystal.