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Guided-wave controlled etalons

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Optical bistability in a nonlinear Fabry–Perot etalon can be controlled by several optical beams injected through the edges of the etalon. The control beams, which propagate transversely in the etalon, modify the refractive index, which in turn switches the etalon between its two stable states. The theory of operation of the device is presented, possible logical operations are discussed and experimental results from using an InSb etalon and a CO laser are reported.

Probably the most promising application of optical bistability is in the area of optical signal processing (Jewell *et al.* 1984; Seaton *et al.* 1983). Switching light by light requires efficient use of the switching power. Guided waves provide an effective means of applying the intracavity intensity needed to switch bistable etalons between their states, independent of the Fabry–Perot resonances. We have proposed and demonstrated experimentally a bistable InSb etalon at 80 K by using a 5.59 μm CO laser beam in which the switching is controlled by a separate beam endfire coupled through the edge of the etalon (Sarid *et al.* 1984). Here we report on the theory and experimental results of the device and present possible applications for the logic operations basic to signal processing.

When a nonlinear Fabry–Perot etalon is used as a bistable device in reflection together with a control beam, as shown in figure 1, the reflected intensity I_{ref} is given by

$$I_{ref} = I_{inc}\left[\!\!\left[1 - \frac{C_1}{1+F\sin^2\{\gamma[(I_{inc}-I_{ref})/C_1C_2+I_{cont}]+\delta\}}\right]\!\!\right]. \quad (1)$$

Here I_{inc} is the incident intensity, I_{cont} is the intensity of an edge-coupled control beam, C_1, C_2, F and γ are constants depending on the geometry and material properties. The detuning δ can be controlled by angle tuning or by scanning along a slightly wedged etalon.

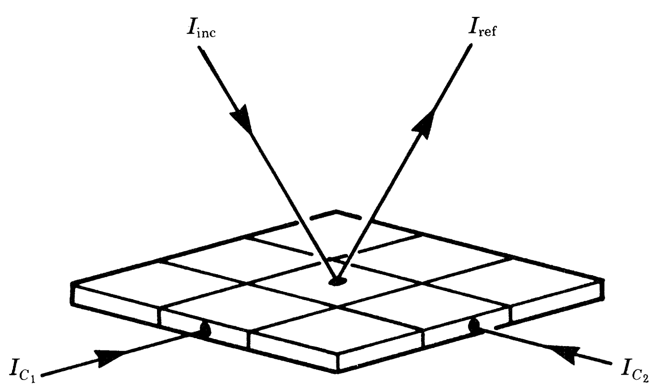

Figure 1. Bistable etalon controlled by two injected beams I_{C_1} and I_{C_2} make optical logic operations.

The concept of controlling bistability by using a guided wave was demonstrated with the experimental arrangement shown in figure 2. The InSb etalon is n-doped with Te (4×10^{14} cm^{-3}), gold-coated on the back face and cooled to 80 K. A beam from a CO laser tuned to 5.59 μm wavelength is split to form the pump and control beams, which are focused onto the face and edge of the etalon, respectively. The incident, reflected and control beam powers are monitored by pyroelectric detectors and displayed on an oscilloscope.

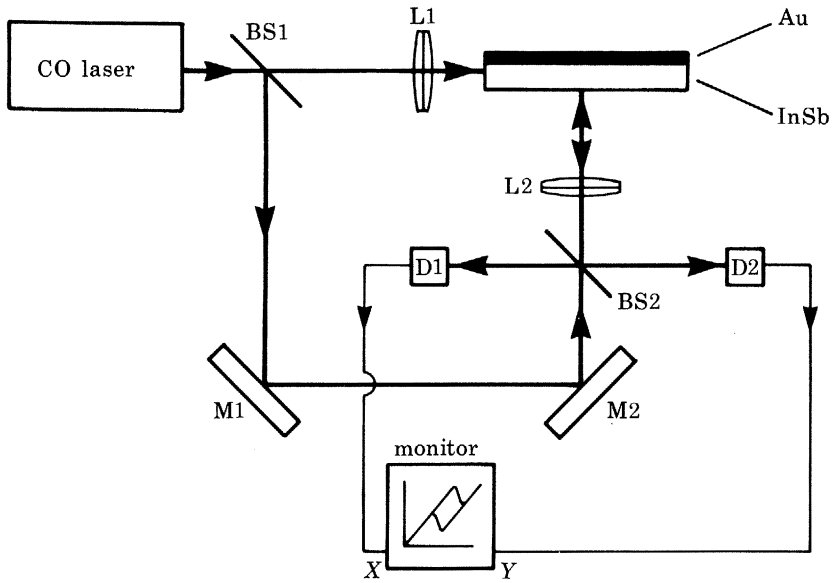

FIGURE 2. The experimental arrangement: BS, beam splitter; L, lens; M, mirror; D, detector.

A typical curve showing the reflected power as a function of control beam power from (1) is given in figure 3. Experimentally, the incident power and detuning can be adjusted to hold the etalon at the 'on' state (point A); by applying the control beam power, the etalon can be switched to the 'off' state (point B).

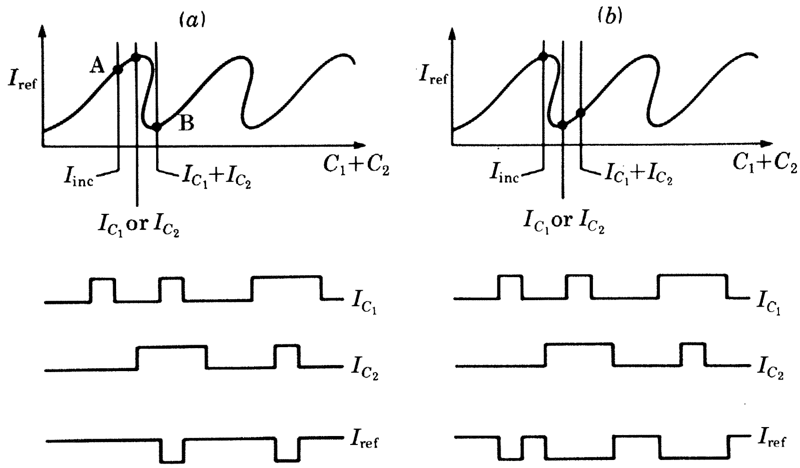

FIGURE 3. Theoretical curves of the reflected intensity as a function of the two control beam intensities, showing operation in reflection as an (a) 'AND' or (b) 'OR' gate.

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The advantage of using a beam injected through the edge of the device to control the switching action is that its effect is decoupled from that of the incident beam. As can be seen from (1), the control intensity I_{cont} serves only to change the detuning of the cavity and does not influence the reflected beam directly, as does the incident intensity I_{inc}. Also, the guided control beam is not affected by the resonances of the etalon and therefore is used efficiently.

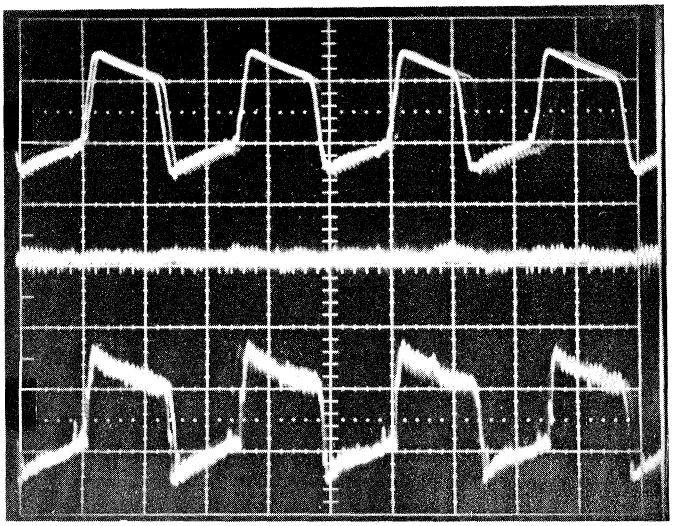

FIGURE 4. Experimental results showing the chopped control beam (upper trace), response of reflected beam to control beam (lower trace, shown inverted) and constant reflected beam (12 mW) in absence of control beam (centre trace). The horizontal scale is 10 ms per division.

The etalon displayed a typical bistable response when operated in reflection. The switching action of the control beam is shown in figure 4, where the upper trace is the modulated control beam power, the centre trace is the constant reflected power in the absence of a control beam, and the lower trace (shown inverted) is the reflected power switched between the 'on' and 'off' states in the presence of a control beam.

By injecting two control beams into a bistable etalon, such as in figure 1, it is possible to make optical logic operations. With the device used in reflection and biased to the appropriate operating point by the incident beam and detuning, 'AND', 'OR' and 'XOR' operations are possible, as illustrated in figure 3. In transmission, 'NAND', 'NOR' and 'NXOR' operations can be made. By fabricating arrays of such devices, more elaborate optical signal processing can be achieved.

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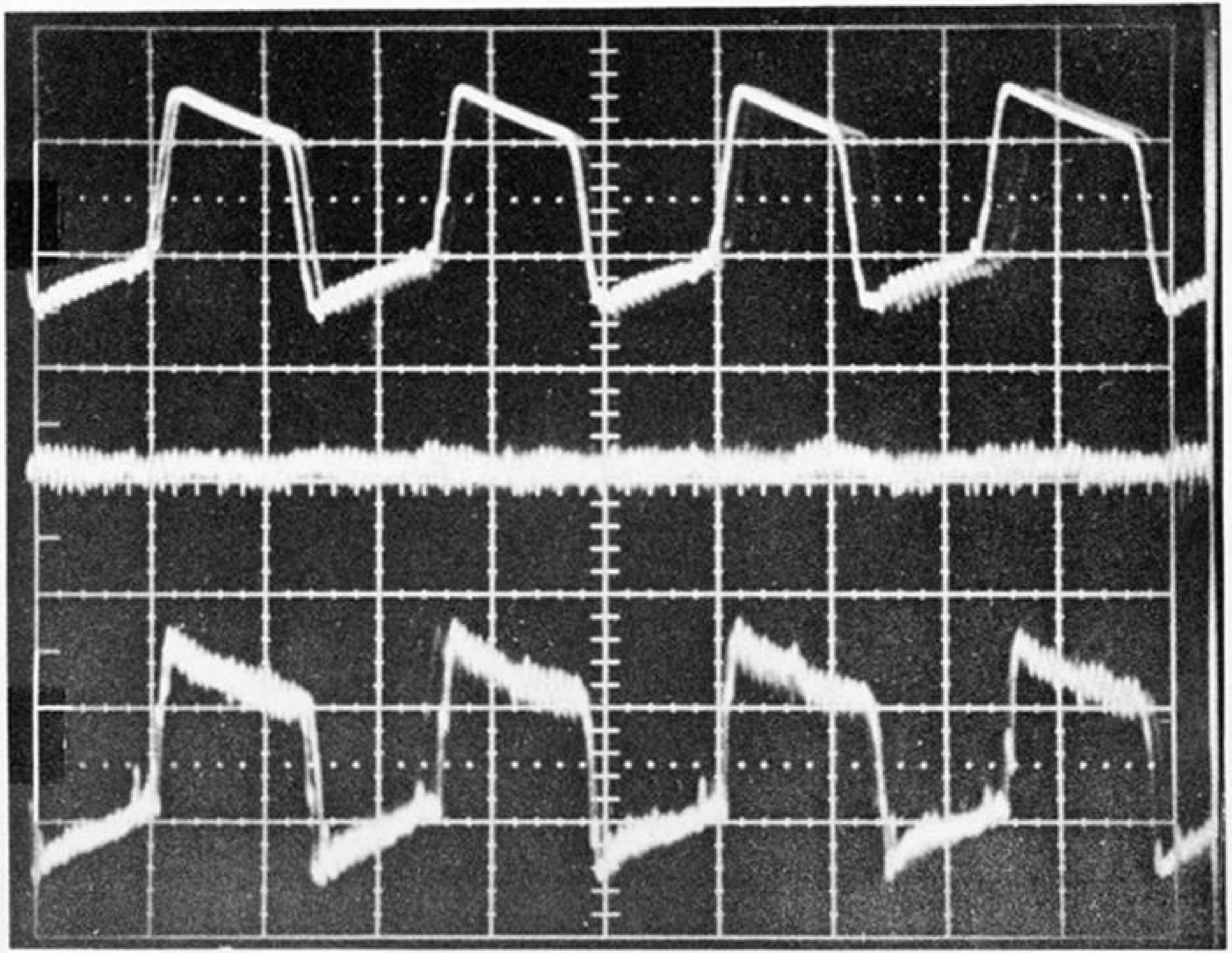

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