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Switching of optically bistable devices by incoherent illumination

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We report the first observation of the external switching of an intrinsic optically bistable device by incoherent radiation. The device, consisting of an InSb etalon held at 85 K and optically biased by a continuous wave CO laser operating at 5.5 μm, was switched both from off to on resonance and from on to off resonance by using a photographic flashlamp. Results presented indicate that the required switching energy per unit area can be of the order of 100 fJ μm^{-2}.

The discovery of giant third-order optical susceptibilities combined with the principles of bistable and nonlinear optical devices has opened up many possibilities for all-optical information processing with real-time optical address. However, to make, for example, a real-time optically addressed spatial light modulator based on these effects it is necessary to be able to switch or modulate a two-dimensional all-optical device with an image impressed in incoherent light (Garmire *et al.* 1978). We report here the first steps toward this goal by the demonstration of external switching of a single bistable device by a white-light incoherent pulse.

Crystals of n-type ($n = 1.9 \times 10^{14}$ cm^{-3}) InSb were used to form Fabry–Perot resonators, the natural reflectivity (*ca.* 0.36) of the plane parallel faces providing a measured coefficient of finesse, F, of 0.8–1.5. The sample thickness, L, was in the range 80–500 μm. An Edinburgh Instruments PL3 continuous wave CO laser operating at 1819 cm^{-1} was used to produce bistability with an incident beam diameter, $1/e^2$, of *ca.* 200 μm. The reflected power was monitored by a fast-response InSb detector. The external white-light switching pulses were incident on the back face of the crystal. They were generated by a photographic flash unit (Sunpak 3600) and dynamically monitored by a Si-photodiode (figure 1). A typical characteristic produced with this arrangment is shown in figure 2 for an etalon with $L = 260$ μm. In the input

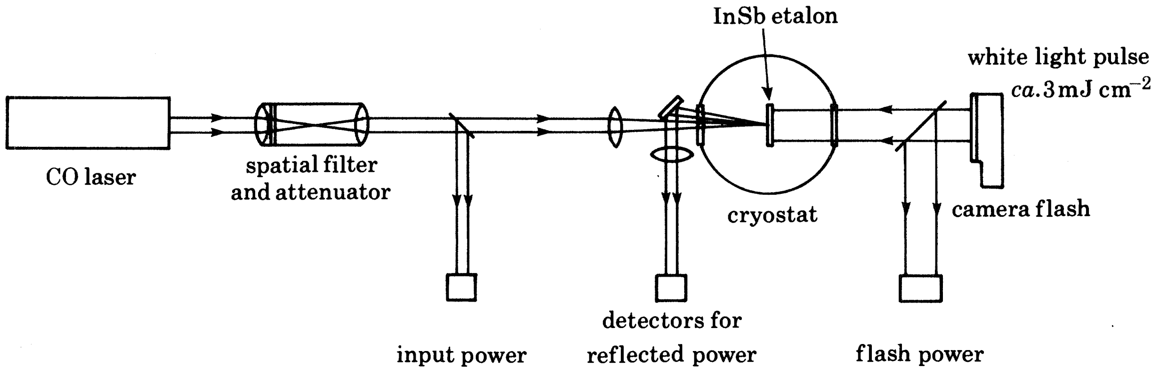

Figure 1. Experimental arrangement used to observe optical bistability and allow introduction of external switching pulses.

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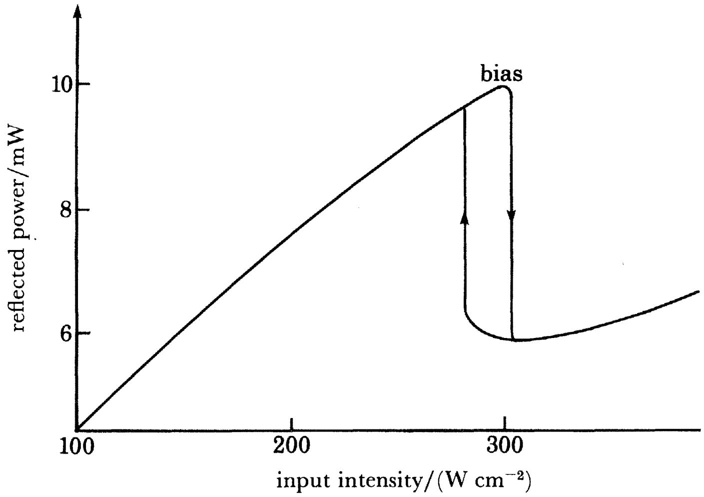

FIGURE 2. Characteristic of a 260 μm thick etalon showing optical bistability in reflection.

power range 47–51 mW the device had two possible output states. Firing the flash unit caused the resonator to switch from off to on resonance.

A critical flash intensity of 39 W cm^{-2} was required when the device was biased with 50 mW (1 mW below switch-on point). Assuming a relaxation time of *ca.* 100 ns for carriers introduced in this manner (Seaton *et al.* 1983), an effective external energy of 1 nJ is calculated as that required to switch the etalon. The total energy involved in switching the etalon should also include that provided by the CO laser during this time. This total energy is comparable to that observed in the only other examples of the external switching of intrinsic bistable systems by Tarng *et al.* (1982) and by Seaton *et al.* (1983). In the latter experiment a similar etalon ($L = 210$ μm) was switched by a 35 ps long pulse of energy 5 nJ, effective over the CO beam area, where the beam derived from a 1.06 μm Nd–YAG mode-locked laser.

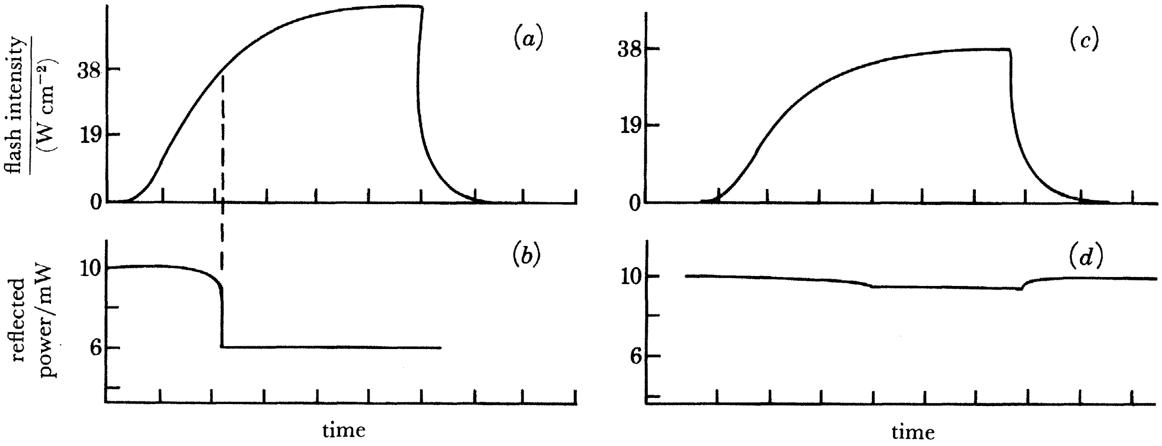

FIGURE 3. (*a*), (*c*). The flash intensity incident on the crystal. (*b*), (*d*) The reflected laser power corresponding to (*a*) and (*c*), respectively. Parts (*c*) and (*d*) show that a high-energy pulse will not switch the etalon if it does not reach a critical intensity. One division represents 50 μs on the time scale.

A thermal effect is concurrent with this electronic one. The absorbed energy heats the sample and this causes a decrease in the energy gap ($\mathrm{d}\bar{\nu}_g/\mathrm{d}T = 2$ cm^{-1} K^{-1} at 80 K (Camassel & Auvergne 1975)). Consequently, the refractive index increases ($\mathrm{d}n/\mathrm{d}T = 6 \times 10^{-4}$ K^{-1} (Cardona

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1960)) as do the nonlinear refractive index and the linear absorption coefficient (these changes can be estimated from Miller *et al.* 1981). The total effect of all three parameters on the input–output characteristic is shown by figure 4. Clearly the increase in linear refractive index is dominant in a sample of this thickness (260 μm). However, in a thinner sample ($L = 98$ μm) the nonlinear part of the characteristic is shifted toward the origin, which suggests that the increase in nonlinear refractive index is dominant.

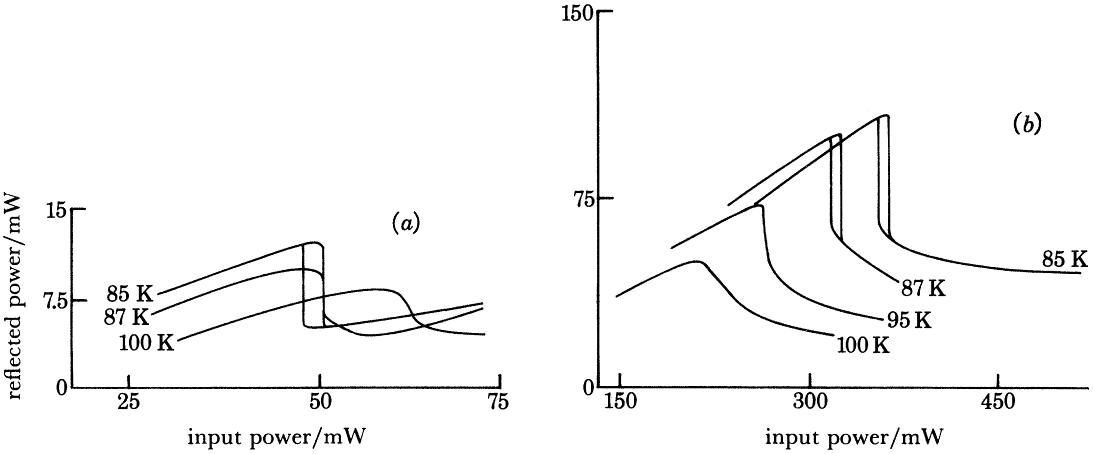

FIGURE 4. The effect of temperature on the characteristics of etalons of thickness (*a*) 260 μm and (*b*) 98 μm.

These shifts can be caused by the heating effect of the flashlamp pulse. For example, figure 5 shows that the absorption of 3 mJ cm^{-2} (enough to raise the temperature by about 2 K) causes switching of the 260 μm thick device from on to off resonance. That this is a purely thermal effect is concluded from the dependence of the switching point upon only the energy absorbed, rather than flash intensity. The 98 μm thick cavity was also switched by using this effect. However, for this cavity the thermal effect causes the etalon to switch from off to on resonance.

In conclusion, we have demonstrated for the first time that an intrinsic bistable device can be switched in both directions between its states by low-energy incoherent white-light pulses.

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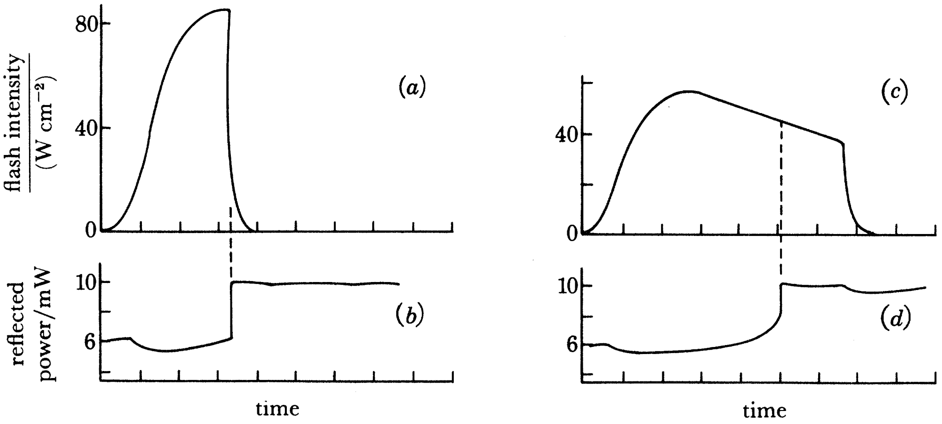

FIGURE 5. As figure 3. The etalon is switched from on to off resonance only when enough energy is absorbed. One division represents 50 μs on the time scale.

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