TRANSIENT PHENOMENA IN BISTABLE OPTICAL DEVICES

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Abstract: We demonstrate both experimentally and theoretically a new mode of transient switching using rapid onset light signals in a bistable optical device with two comparable time constants. Four distinct transmission modes for input pulse trains have been observed, one of which produces a subharmonic of the input pulse train by alternate overshoot switching.

I. INTRODUCTION

There has been considerable recent interest in bistable optical devices (BOD's), nonlinear optical devices whose output may be multi-valued with respect to input. This phenomenon is typically obtained with a nonlinear Fabry-Perot or with a hybrid electrical/optical device. The steady state characteristics of these devices are now fairly well understood and recent emphasis has been directed toward the transient response of these devices. In this paper we turn our attention to BOD's which have two comparable time constants. We will show that it is possible for a BOD to switch at incident light levels considerably smaller than the critical incident signals in steady state operation. This effect occurs for rapid onset input signals when the device has two time constants of roughly equal value. The discovery of overshoot switching will have a significant impact on BOD's whose feedback time constants approach their internal time constants. Both hybrid BOD's and nonlinear Fabry-Perots may show overshoot switching. In this paper we emphasize the hybrid BOD, since this device is most easily amenable to experimental verification. We will show that the theory and experiment are in excellent numerical agreement. Similar analyses of other hybrid configurations
and of the nonlinear Fabry-Perot lead to similar results.  

When a train of pulses is incident on a BOD, there is a regime of operation in which the device switches alternately yielding an output which is a subharmonic of the input pulse train. We demonstrate this effect both experimentally and theoretically in hybrid devices. In addition, we predict its existence in the all-optical BOD's such as the nonlinear Fabry-Perot.

II. OVERSHOOT SWITCHING

The hybrid BOD used for our theoretical analysis and experimental studies is the same as that used previously. It consists of a LiNbO\(_3\) polarization modulator driven by the output of a photoconductor which monitors the transmission of the BOD. The time constants in the device come from the rise-time of the photoconductor and from a variable capacitance placed across the biasing resistor. Figure 1 shows the steady-state transfer curve of the experimental BOD used to demonstrate overshoot switching. The critical incident light level required for switching to the high transmission state under steady-state operation is indicated by \(I_c\). \(I_s\) represents the experimentally measured critical incident signal for switching with a rapid onset input. The fact that this incident intensity is considerably below the steady-state value is the result of overshoot switching.

It can be shown that the dynamic response of the hybrid BOD with two time constants may in general be represented by an equation for the voltage across the modulator,\(^5\)

\[
m \frac{d^2v}{dt^2} = T(v) I_i - v - \alpha \frac{dv}{dt}
\]

Fig. 1. Voltage across the modulator of the BOD (vertical) vs. incident light intensity (horizontal). \(I_c\) is the steady-state switching intensity, \(I_s\) is the minimum overshoot switching intensity.

\[\text{(1)}\]