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Bistable switching in nonlinear Bragg gratings.

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Abstract

We present a new approach to all-optical switching in nonlinear Bragg gratings. In contrast to previous schemes in which the system remains in the switched state for a short length of time we permanent switch a CW probe from a state of high reflectivity to a low reflectivity state using a short optical pump. Finally we discuss the practicality of the device.

42.65.-k,42.65.Pc,42.70.Qs,42.81.-i

I. INTRODUCTION

Fibre Bragg gratings (FBGs) are emerging as one of the essential components for the next generation of all-optical networks due to their low insertion losses, narrow bandwidths, and high reflectivities. Furthermore these linear features make Bragg gratings particularly interesting nonlinear devices. Indeed it has been shown that a high power pump pulse can significantly alter the propagation of a weak CW probe beam as they co-propagate through the grating [1,2]. These experiments, which relied on the cross phase modulation effect in fibres [3], showed that it was possible to alter the transmission of a probe by the grating in the presence of the pump. When the pump left the grating the transmission of the probe returned to its initial state. Clearly a system in which the propagation of the pump permanently altered the transmission of a probe would be more desirable having obvious applications in all-optical memory and for packet switching in all-optical networks. Fortunately the transmission of nonlinear Bragg gratings is bistable [4] suggesting that it might be possible to permanently switch a Bragg grating using a pump pulse and indeed we present such a scheme below.

Crucial to this scheme is the nonlinear response of a FBG to an intense CW excitation. Winful *et al.* showed that the under these conditions the transmission (and reflection) of Bragg grating exhibits bistable behaviour [4]. Fig. 1 shows the transmission of a uniform Bragg grating as a function of the input intensity. Note that for a range of input intensities the transmission of the grating can be in a variety of states. Which particular state it is in depends on the history of the device, which is the essence of this scheme. The experiments discussed previously operated in the low power region of Fig. 1 where only one state exists and hence the initial and final states of these experiments were identical. In contrast I propose to operate at a input intensity near the dashed line in Fig. 1 where the grating is bistable. The initial and final states are given by the two solid dots in Fig. 1. We note that the middle branch of the transmission curve has been shown to be unstable [5] and hence we ignore it in this work. In the next section I present a theoretical model of our switch and we can write the coupled mode equations (CME) for $f_\pm$ as [6]

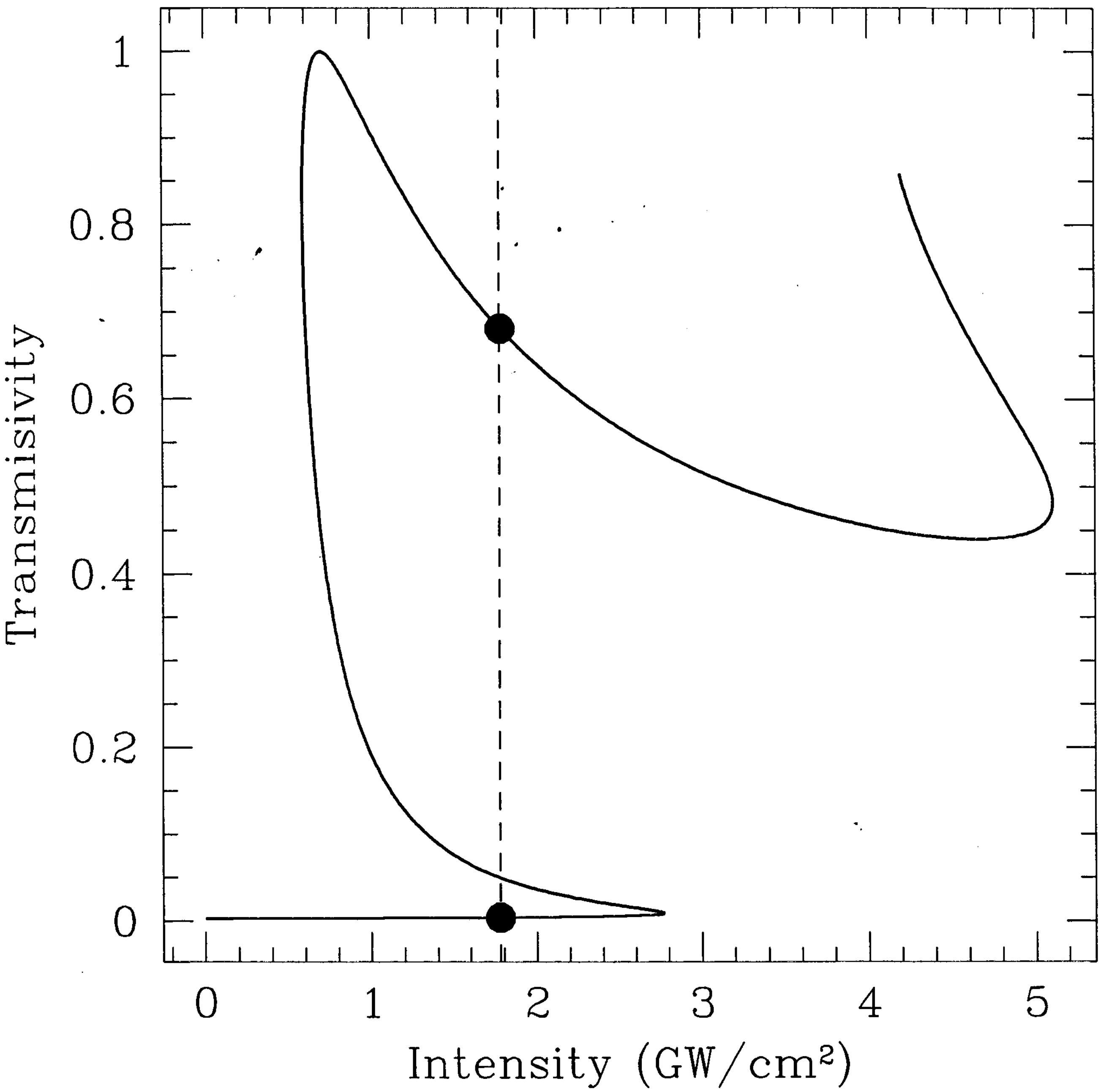
$$i\frac{\partial f_+}{\partial z} + \frac{i}{v_g}\frac{\partial f_+}{\partial t} + \kappa f_- + \delta f_+ + 2\Gamma|f_-|^2 f_+ + \Gamma|f_+|^2 f_+ + \frac{2}{3}\Gamma|P(z,t)|^2 f_+ = 0, \tag{2a}$$

$$-i\frac{\partial f_-}{\partial z} + \frac{i}{v_g}\frac{\partial f_-}{\partial t} + \kappa f_+ + \delta f_- + 2\Gamma|f_+|^2 f_- + \Gamma|f_-|^2 f_- + \frac{2}{3}\Gamma|P(z,t)|^2 f_- = 0. \tag{2b}$$

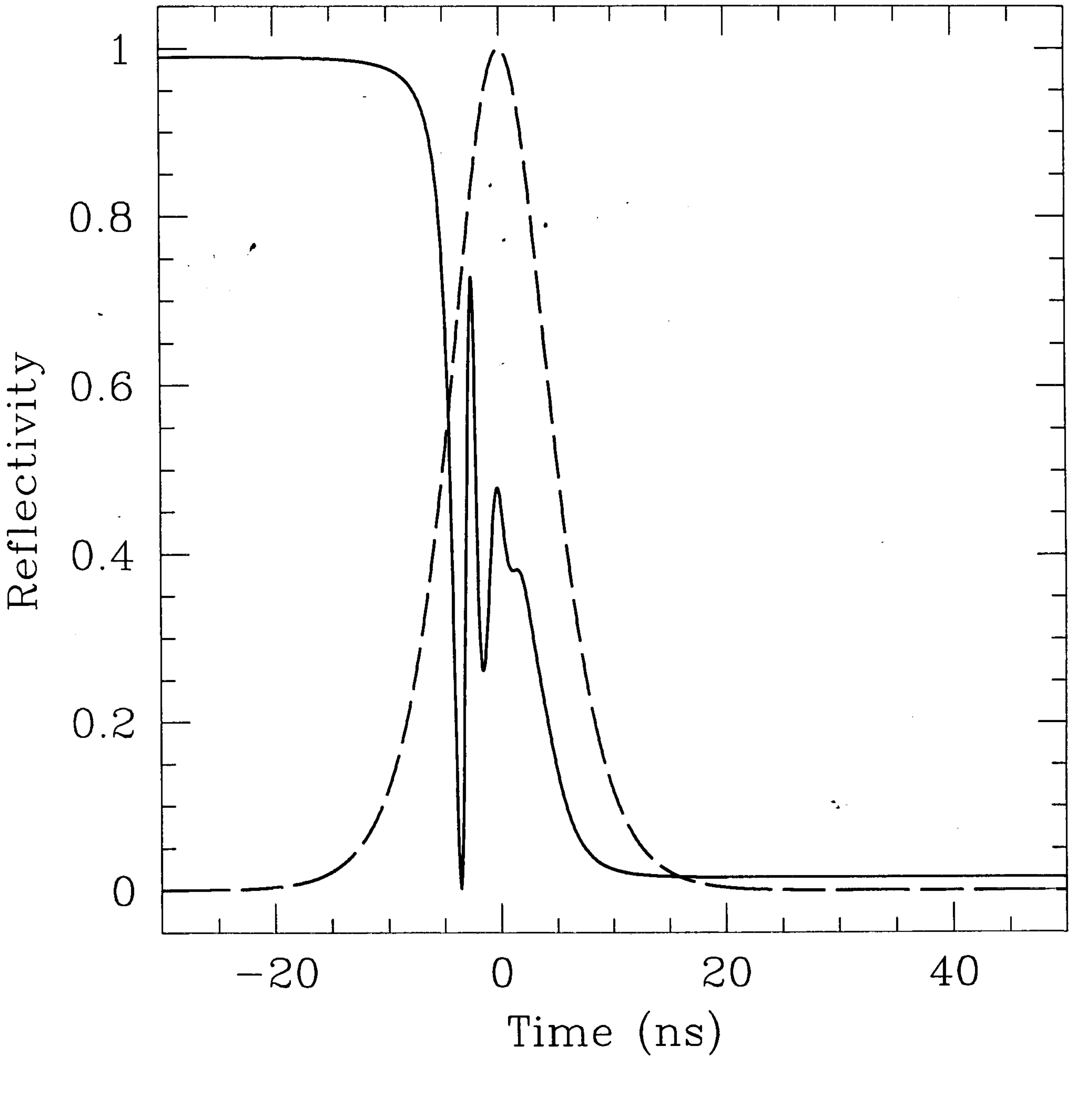
We have assumed that the pump propagates unchanged through out the fibre, i.e. $P(z,t) = P(z - v_g t)$. For an optical fibre we have [7,8]:

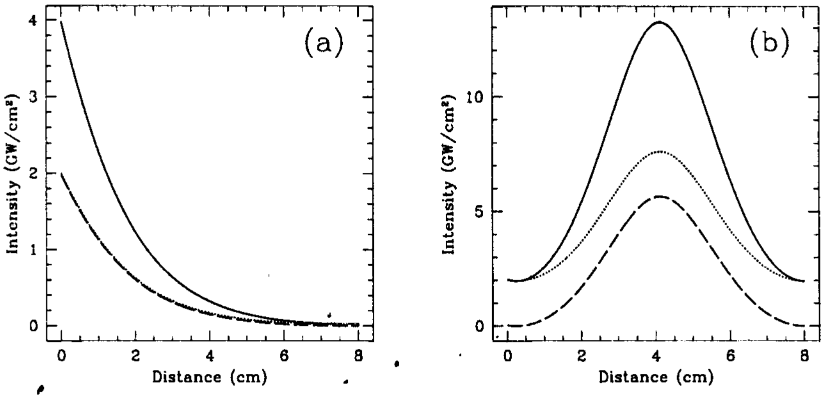
$$\delta = \frac{\omega - \omega_0}{v_g}, \quad \Gamma = \frac{4\pi n_0}{\lambda Z} n^{(2)}, \tag{3}$$

n_0 is the average refractive index of the FBG, v_g is the group velocity in the absence of a grating, λ is the free space Bragg wavelength and Z the vacuum impedance. The strength of the nonlinearity is given by $n^{(2)}$ which equals $3 \times 10^{-20}\,\mathrm{m}^2/\mathrm{W}$ in silica [3]. The parameter κ measures the strength of the coupling between f_+ and f_- and is proportional to the



Transmisivity
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
Intensity (GW/cm²)


1
0.8
0.6
0.4
0.2
0
Reflectivity
−20
0
20
40
Time (ns)


(a)
Intensity (GW/cm²)
Distance (cm)
(b)
Intensity (GW/cm²)
Distance (cm)