PULSE SWITCHING IN A LOSSY ACOUSTO-OPTIC TUNABLE FILTER (AOTF)

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ABSTRACT

In this paper, we did a study of the transmission characteristics of the AOTF operating with ultrashort light pulses(2ps). Initially one consider the performance of the device, operating in the nonlinear regime without loss. It was observed that the effect of dispersion and nonlinearity, has strong influence on the pulse propagation when one increase the length of the AOTF. For shorter length of the device the switched pulse is presenting time broadening. For higher length of the device, pulse breakup was observed. Considering the AOTF with loss one consider the device of length 0.25mm with loss of 4dB/mm constructed with an increasing nonlinearity profile. It was observed that the increase of the nonlinearity lead the switched pulse from broadening to optical compression. One can say that one can operate the AOTF in a configuration that one can avoid the pulse break up and have a switched pulse with a shorter time duration compared with the lossy AOTF. The study of the AOTF operating with ultra short optical solitons provides possibilities for achieving, high efficiency in ultrafast all-optical signal processing, especially for optical switches, filters and optical transistors.

1-INTRODUCTION

The acoustic-optic tunable filter (AOTF) has attracted great attention in recent years, in part because it appears to be a suitable basis for multi-wavelength optical cross-connects. It is probably the only known tunable filter that is capable of selecting several wavelengths simultaneously. This capability can be used to construct a multi-wavelength router.

Cross-connects are important in multi-wavelength networks because they can enable reconfigurable network architectures that can adapt to changing traffic patterns and enhance network survivability. A multi-wavelength cross-connect capable of switching a moderate number of wavelengths could enable multihop networks providing access to millions of network nodes with a reasonable number of hops. The AOTF is attractive for this application because it provides simultaneous, transparent and nearly independent switching of many closely spaced and arbitrarily chosen wavelength channels, a large and flexibly addressed wavelength range, rapid tuning (order of a few μs) across the accessible wavelengths, low optical loss (3-4 dB/stage), and the potential for integration of several functions on the same substrate. Recent improvements in the AOTF design included passband engineering to reduce sidelobs, flatten the wavelength response, which reduce the crosstalk and increase the channel-width-to-channel-spacing ratio. In this paper, we did a study of the transmission characteristics of the AOTF operating with ultrashort light pulses (2ps of time duration-1ps=10^{-12}s). Initially one consider the performance of the device, with several length, operating in the nonlinear regime without loss and in the presence of loss. Considering the loss, one has investigated the effect of the increasing self phase modulation (SPM) profile on the performance of the AOTF. The linear SPM profile have been considered. From our study of the linear SPM profile, we observed that for the nonlinear AOTF with loss, the increasing nonlinear profile could lead to pulse compression or pulse break up depending on the length of the AOTF, the magnitude of the loss. From our study of the linear SPM profile, we suggest the best region of the nonlinearity parameter to recover the original performance in the nonlinear transmission of the AOTF, to overcome the effect of the intrinsic loss in the device.

2. BASICS OF THE AOTF

The AOTF is shown schematically in Figure 1. It consists of an optical waveguide occupying the same space as an acoustic waveguide. The acoustic wave is introduced into the acoustic guide using a surface acoustic wave (SAW) transducer. The acoustic field acts on the optical fields in the interaction region to convert the TE polarization to a TM mode, and vice versa. This interaction is frequency selective because of the requirement for momentum matching for significant interaction. The polarization conversion efficiency can be calculated by treating the device as a classical directional coupler, where the coupled modes are the TE and TM modes of the optical waveguide, and the coupling coefficient is proportional to the acoustic amplitude.

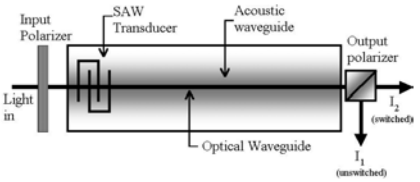

Figure 1: Schematic of the acoustic optic tunable filter (AOTF).

3. THEORETICAL FRAMEWORK

We will consider picosecond pulses propagating in the anomalous dispersion regime in an AOTF. The propagation of ultrashort nonlinear pulses through the AOTF is described by the nonlinear Schrödinger For the sake of convenience we neglect the weak nonlinear cross-phase modulation (XPM). The coupled differential equations describing the evolution of the slowly varying complex modal amplitudes a_1 and a_2 (TE and TM modes respectively) are:

$$i\frac{\partial u_1}{\partial \xi}+\frac{1}{2}\frac{\partial^2 u_1}{\partial \tau^2}+Q(\xi)\,|u_1|^2\,u_1+Ku_2-\Delta\beta u_1+i\Gamma u_1=0$$

(1)

$$i\frac{\partial u_2}{\partial \xi}+\frac{1}{2}\frac{\partial^2 u_2}{\partial \tau^2}+Q(\xi)\,|u_2|^2\,u_2+Ku_1+\Delta\beta u_2+i\Gamma u_2=0$$

(2)

where u_1 and u_2 are the modal field amplitudes, $\Gamma=(\alpha L_D)/2$ is the normalized optical loss over one dispersion length (α is the optical loss), K is the linear coupling coefficient between TE and TM modes, $\Delta\beta=\beta_{TM}-\beta_{TE}$ is the phase mismatch of the modes, $Q(\xi)$ denotes the SPM profile, which is proportional to the nonlinear refractive index n_2 of the guide.

4-RESULTS AND DISCUSSION

In this paper, we do a study of the AOTF, where the optical guide present an increasing SPM profile (Q(z)). We study the linear profile. This profile expressed in terms of the parameters β(maximum value of Q) and L (length of the AOTF) is :

$$Q(\xi)=\frac{(\beta-1)}{L}\xi+1 \qquad \text{Linear}$$

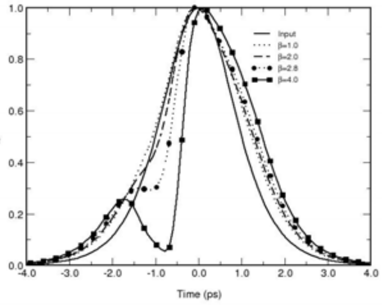

Figure 2: Time Intensity of the input and switched pulse for ξ_L =L/3 (L=0.76mm)solving equations (1)+(2) with $K\xi_L=\pi/2$, $\Gamma=0.035$ ($\alpha\approx$4dB/mm) and β=1,2,2.8,4.

In figure 2 one shows the input time profile and the switched pulses for four different values of the β parameter (β=1,2,2.8 and 4) in the presence of loss ($\alpha\approx$ 4dB/mm). For β=1 (no profile) the switched pulse is presenting broadening (C=1.15 in figure 5, $T_2\approx2.3$ ps). With the increase of the β parameter the pulse is showing break-up where the more intense pulse is shorter than the input pulse. In figure 3 one has the switched spectrum of the pulses are getting broader where a strong asymmetry is developing from β=2. One can say that one can operate the AOTF in a configuration that one can avoid the pulse break up and have a switched pulse with a shorter time duration (β=2 T_2=2.16ps see figure 5 and 6 a) compared with the lossy AOTF ((β=1 T_2=2.3ps see figure 5 and 6 a).

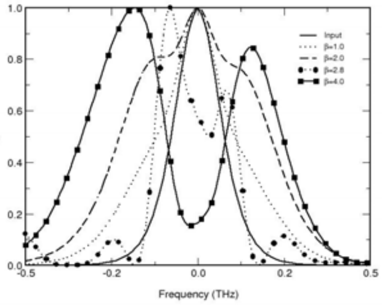

Figure 3: Frequency Intensity of the input and switched pulse for ξ_L =L/3 (L=0.76mm) solving equations (1)+(2) with $K\xi_L=\pi/2$, $\Gamma=0.035$ ($\alpha\approx$4dB/mm) and β=1,2,2.8,4.

CONCLUSIONS

In this paper, we did a study of the transmission characteristics of the AOTF operating with ultrashort light pulses(2ps). Initially one consider the performance of the device, with several lengths, operating in the nonlinear regime without loss. It was observed that the effect of dispersion and nonlinearity, has strong influence on the pulse propagation when one increase the length of the AOTF. For shorter length of the device the switched pulse is presenting time broadening. For higher length of the device, pulse breakup was observed. Considering the AOTF with loss one consider the device of length 0.25mm with loss of 4dB/mm constructed with an increasing nonlinearity profile. It was observed that the increase in β (increase of the final value of the profile $Q(\xi)$ of the nonlinearity) lead the switched pulse from broadening to optical compression. One can say that one can operate the AOTF in a configuration that one can avoid the pulse break up and have a switched pulse with a shorter time duration compared with the lossy AOTF. This configuration is possible with $\beta=2$ which result in a switched pulse with $T_2=2.16$ps, which is shorter compared with the lossy AOTF ($\beta=1$ $T_2=2.3$ps)

The study of the AOTF operating with ultra short optical solitons provides possibilities for achieving, high efficiency in ultrafast all-optical signal processing, especially for optical switches, filters and optical transistors. The acoustic-optic tunable filter (AOTF) has attracted great attention in recent years, in part because it appears to be a suitable basis for multi-wavelength optical cross-connects. It is probably the only known tunable filter that is capable of selecting several wavelengths simultaneously. This capability can be used to construct a multi-wavelength router.

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