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 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 sidelobes, 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=10⁻¹²s). 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.
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:

$$i\frac{\partial a_1}{\partial \xi} + \frac{1}{2} \frac{\partial^2 a_1}{\partial \tau^2} + Q(\xi) |a_1|^2 a_1 + Ku_2 - \Delta \beta k u_1 + i\Gamma u_1 = 0$$

(1)

$$i\frac{\partial a_2}{\partial \xi} + \frac{1}{2} \frac{\partial^2 a_2}{\partial \tau^2} + Q(\xi) |a_2|^2 a_2 + Ku_1 + \Delta \beta k u_2 + i\Gamma u_2 = 0$$

(2)

where $a_1$ and $a_2$ are the modal field amplitudes, $\Gamma=(\alpha L_n)/2$ is the normalized optical loss over one dispersion length ($\alpha$ 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 ($Q(\xi)$). We study the linear profile. This profile expressed in terms of the parameters $\beta$(maximum value of $Q$) and $L$ (length of the AOTF) is:

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

Linear

In figure 2 one shows the input time profile and the switched pulses for four different values of the $\beta$ parameter ($\beta=1,2,2.8$ and 4) in the presence of loss ($\alpha \approx 4dB/mm$). For $\beta=1$ (no profile) the switched pulse is presenting broadening ($\Delta \beta = \pi/2$, $\Gamma=0.035$ ($\alpha \approx 4dB/mm$) and $\beta=1,2,2.8,4$).

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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 $\beta$ (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 $T_2=2.16ps$, which is shorter
compared with the lossy AOTF ($\beta=1$ $T_2=2.3ps$)
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)
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REFERENCES

Cheung, “Integrated optic acoustically-tunable infrared
optical filter”, Electron. Lett. Vol 24, pp 1562-1563,
1988
(AOTF’s) for multiwavelength optical cross-
connects:Crosstalk considerations, J. Lightwave
mode converters with weighted coupling using surface
acoustic wave directional couplers, Electron. Lett. Vol
28, pp 979-980 (1992)
tunable filters for WDM networks” IEEE J. Celect.
Areas Commun., vol 8 pp 1151-1159 (1990)