Acousto-Optics and Applications

Acousto-Optic Tunable Filters for Imaging Applications in the 2–4 μm with Low RF Drive Power

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The λ^2 dependence on acoustic field intensity (and hence RF drive power) can render large aperture acousto-optic tunable filters impractical for many applications beyond about 2 μm. One potential technique for reducing the RF drive-power requirement is to configure an acousto-optic tunable filter such that the interaction region is at acoustic resonance. We describe an acousto-optic tunable filter that operates at resonance and present an analysis of the predicted performance. In addition, we address the practical issues in deploying such a scheme. Finally, we present results of a prototype "resonant acousto-optic tunable filter" operating in the 1–2 μm region.

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1. Introduction

The acousto-optic tunable filter (AOTF) exploits the slow-shear anisotropic interaction to realize a solid-state agile random-access electronically addressable tunable filter [1]. Two configurations are commonly used: the quasi-collinear configuration, where the direction of the incident beam is parallel with the acoustic walk-off [2], and non-collinear configuration, where acoustic wave and incident beam are transversal. In order to maximize the field of view the non-collinear configuration satisfies the parallel tangent matching condition [3].

2. Diffraction efficiency

The diffraction efficiency is given by [1]:

$$\eta = \frac{I_\mathrm{d}}{I_0} \approx \sin^2 \sqrt{\frac{\pi^2 M_2(\lambda_0,\theta_\mathrm{a}) P_\mathrm{a}}{2\lambda_0^2}\frac{L_\mathrm{a}}{H}}, \quad (2.1)$$

where M_2 is the acousto-optic figure of merit, P_a is the acoustic power, L_a is the interaction length, H is the height of the acoustic field, λ_0 is the wavelength of the electromagnetic spectrum. The acoustic power required to achieve peak diffraction efficiency (PDE) is theoretically estimated by

$$P_\mathrm{PDE} = \frac{\lambda^2}{2M_2(\lambda_0,\theta_\mathrm{a})}\frac{H}{L_\mathrm{a}}, \quad (2.2)$$

which increases with λ^2 and depends on the ratio H/L_a. In the wavelength range between 400 nm and 4.5 μm, the most common material used in acousto-optic devices is tellurium dioxide (TeO_2) due to the favourable acoustic-optic properties. In case of conventional AOTF made of TeO_2 the ratio H/L_a is usually between 0.28 and 1, under this condition the acoustic power for full diffraction efficiency increase above practical level (> 5 W) in the wavelength range between 2.0 μm and 4.5 μm.

3. Resonant configuration

The high RF power required for full diffraction efficiency is one of the practical limitations for imaging AOTF up to 4.5 μm [4]. A solution to obtain more practical devices is to configure a non-collinear AOTF where the acoustic field is in acoustic resonance, where phonons are "recycled" after the first AO interaction (Fig. 1). This configuration is particularly suitable for wavelength range between 2 μm and 4.5 μm, because the acoustic attenuation, which depends on f^2, is lower due to the operational frequency range under the parallel tangent matching configuration in IR range.

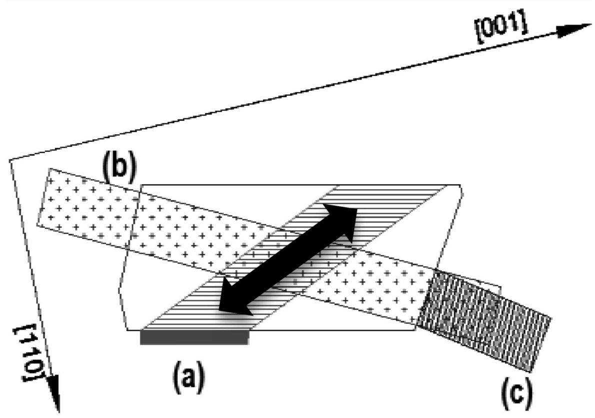

Fig. 1. Resonant AOTF configuration, acoustic field (a), 0th order (b), 1st order (c).

4. Experimental results

A first prototype of a resonant AOTF operating in the wavelength range between 1 μm and 2 μm has been built and tested. The RF power for full

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diffraction efficiency for different wavelengths has been measured using a supercontinuum source and optical spectrum analyser. The experimental results have been compared with the predicted values of a conventional and a resonant AOTF (Fig. 2).

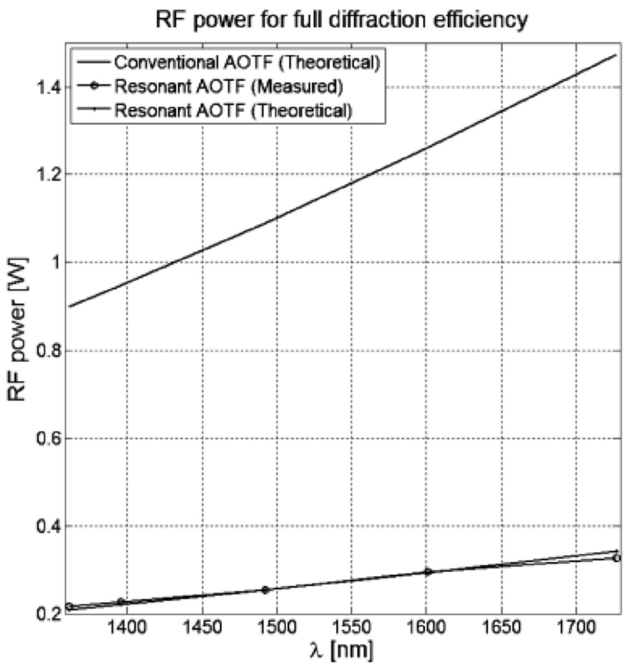

Fig. 2. Comparison on RF power for PDE in case of a conventional and a resonant devices.

5. Conclusion

The reduction of the RF power for PDE is in good agreement with the model developed and as expected the advantage factor depends on the acoustic wave attenuation. The resonant configuration is more suitable for filtering optical radiation between 2 μm and 4.5 μm in case of AOTF made of TeO_2. In conclusion, the resonant configuration might be a solution to designed imaging AOTF for $\lambda > 2$ μm, with low RF power for PDE, with large aperture. An optimized configuration for the wavelength range 2–4 μm is currently under investigation.

Acknowledgments

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