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# Extraordinary enhancement of Second Harmonic Generation in cavity-resonator integrated grating couplers

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## ABSTRACT

Cavity resonator integrated grating filters (CRIGF) [1] are composed with a sub-wavelength coupling grating of a few tens of periods (GC), surrounded with two distributed Bragg reflectors (DBR), etched on a multilayer stack of lossless dielectric materials (see Fig. 1). Illuminated with an incident beam overlying the GC, CRIGF exhibit resonances characterised by a strong electromagnetic field concentrated in the guiding layer beneath the structuration. We are currently exploiting this property to enhance second order nonlinear optical effects, in particular second harmonic generation (SHG) [2]. The main applications targeted in the long term are efficient and compact optical sources in wavelength ranges where technological solutions are rare. For this exploratory work, we are interested in the conversion from 1.55 $\mu\text{m}$  to 775nm.

**Keywords:** resonant waveguide gratings, second-harmonic generation.

## 1. INTRODUCTION

Cavity resonator integrated grating filters (CRIGF) [1] are composed with a sub-wavelength coupling grating of a few tens of periods (GC), surrounded with two distributed Bragg reflectors (DBR), etched on a multilayer stack of lossless dielectric materials (see Fig. 1). Illuminated with an incident beam overlying the GC, CRIGF exhibit resonances characterised by a strong electromagnetic field concentrated in the guiding layer beneath the structuration. We are currently exploiting this property to enhance second order nonlinear optical effects, in particular second harmonic generation (SHG) [2]. The main applications targeted in the long term are efficient and compact optical sources in wavelength ranges where technological solutions are rare. For this exploratory work, we are interested in the conversion from 1.55 $\mu\text{m}$  to 775nm.

## 2. FIELD ENHANCEMENT AND SECOND-HARMONIC GENERATION SIGNAL

Figure 1 give a schematic view of the structure. It consists of a dielectric waveguide made of lithium niobate divided in three grating structures: central GC part and 2 DBR mirrors, separated by 2 PS plane regions.

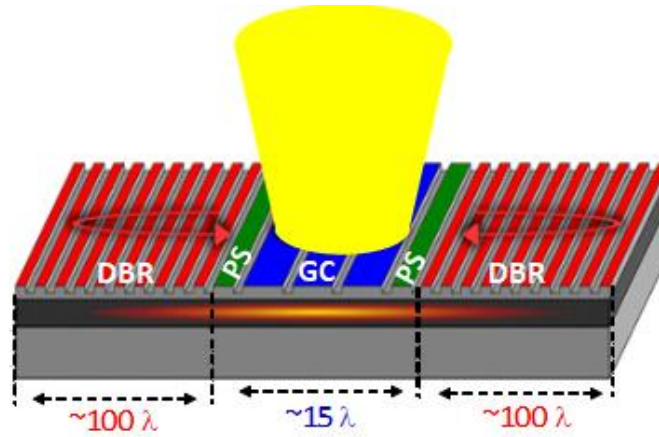


Figure 1. CRIGF device

Numerical modelling is carried out at the Fresnel Institute (Marseille), using in-house codes, in the undepleted-pump approximation [3]. The fabrication and optical characterisation are carried out at LAAS-CNRS (Toulouse). In our first work [2], we reached numerically and experimentally a conversion efficiency of the order of  $8 \times 10^{-6} \text{ W}^{-1}$ . This conversion efficiency is one order of magnitude higher than those achievable with infinite resonant gratings [4], but two orders of magnitude lower than those of the much longer ribbon guide components [5].

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However, the structure was not optimised to exalt SHG, and the full potential of CRIGF remains to be exploited, particularly in two ways. The first way is to also excite a mode at the signal frequency, in phase with the mode at the pump frequency. This could be achieved by taking advantage of the anisotropy of  $\text{LiNbO}_3$ , or by introducing additional layers into the stack.

The second way, which we are currently exploring, consists in increasing the quality factor  $Q$  (ratio of the resonance wavelength to its spectral width) of the resonance at the pump, and thus its field inside the component. The resonances in a CRIGF are Fabry-Perot resonances of guided modes, which leak through the GC region. The quality factor of the resonance can thus be increased by decreasing this leakage. One possible application is a quasi-dark mode [6] of the GC region. In a symmetric DBR box, it is possible to displace the central grating by choosing different PS lengths, so that a symmetric DBR mode becomes a quasi-antisymmetric GC mode, Fig.2.

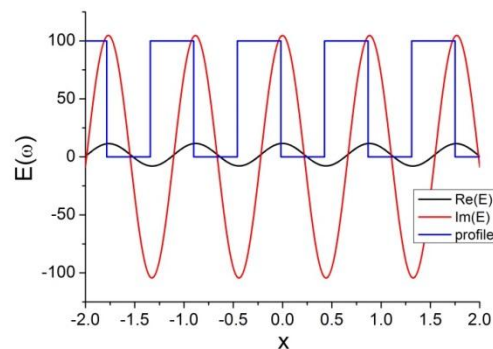
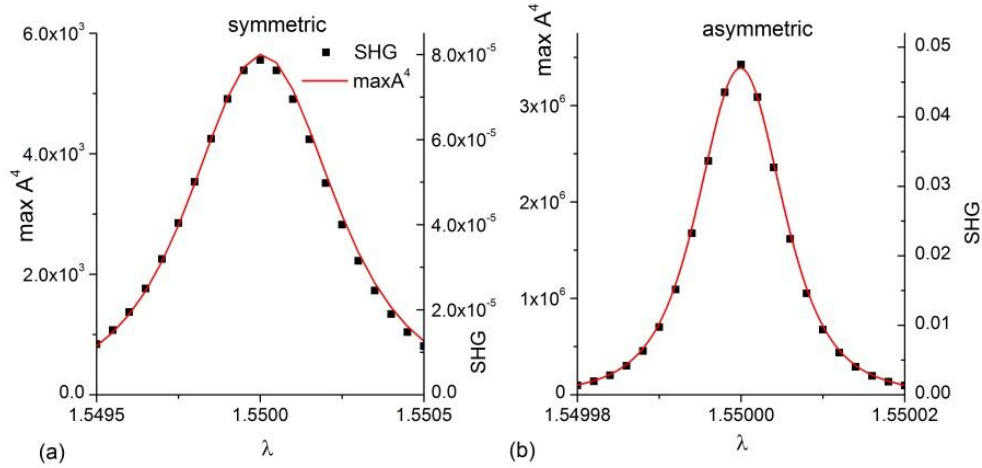


Figure 2. Spatial electromagnetic field distribution. Asymmetric structure No. 2 in close vicinity of the system center. The blue line represents the GC profile, shifted with respect to  $x = 0$ .

The result is that it is possible to enhance the electric field density by a factor of 1000, when compared with the bright mode excitation, Fig.3, which gives a formal increase of 106 of the SHG signal. It is necessary to stress



that this increase is only valid within the non-depleted pump approximation.

Figure 3. Spectral dependence with respect to the pump wavelength of the mode amplitude and the SHG of the a) asymmetric and b) symmetric structure

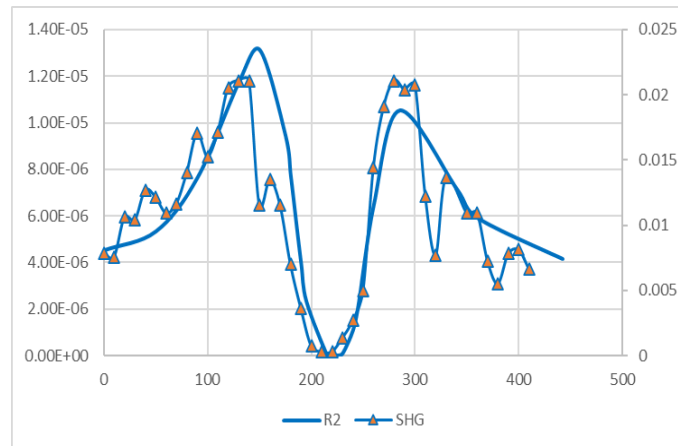


Figure 4. SHG as a function of the asymmetry of the GC position with respect to the DBR box (the relative difference nm between the lengths of the two PS regions in Fig.2). Triangles, experimental values on the left scale, full curve, the numerical results

Figure 4 gives a comparison between the theoretical and experimental data of the SHG signal as a function of the asymmetry of the structure. The latter is maximum at 220 nm and zero at 0 and 440 nm.

Although the conversion efficiencies predicted numerically are not reached, these components are nevertheless very promising.

## ACKNOWLEDGEMENTS

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