Résumé.

Titre : Génération de seconde harmonique dans des structures à réseaux résonnants en cavité.

La génération de seconde harmonique (SHG) est un processus optique non-linéaire du deuxième ordre correspondant à la création d'un signal optique à une fréquence 2ω à partir d'un signal à une fréquence fondamentale ω, lors du passage de cette onde dans un milieu non-linéaire. Les domaines d'application de la SHG sont très nombreux : stockage de données, imagerie biologique, optique quantique, sources laser, etc. Cependant, pour réussir à obtenir une SHG efficace, des conditions expérimentales particulières sont nécessaires. Une de ces conditions est notamment d'avoir le champ électrique de pompe le plus important possible. Pour obtenir ce fort champ tout en gardant une puissance raisonnable pour le laser de pompe, il est possible d'utiliser des dispositifs nanophotoniques permettant d'exalter le champ électrique local.
Les dispositifs que nous avons étudiés lors de cette thèse sont appelés « CRIGFs » (Cavity Resonator Integrated Grating Filters) et constituent une nouvelle famille de filtres spectraux fonctionnant en réflexion. Un CRIGF est une structure à réseaux résonants de faible dimension (quelques centaines de λ de long) formant un résonateur de fort facteur de qualité, excitable depuis la surface à l'aide d'un faisceau fortement focalisé. Ces propriétés font du CRIGF une structure potentiellement très intéressante pour exalter le champ électrique de pompe, et donc d'exalter la SHG.
Nous présentons dans cette thèse différentes structures CRIGFs non-linéaire, permettant d'exalter de manière importante la SHG. Dans un premier temps, ces structures ont été conçues selon les méthodes établies, c'est à dire comme des filtres spectraux en réflexion. Le point de départ de cette méthode est l'obtention d'un empilement constituant un bon anti-reflet autour de la longueur d'onde d'excitation.
Dans un second temps, nous avons développé une nouvelle méthode de conception propre au CRIGF non-linaire, reposant sur un empilement plus simple et basée sur la maximisation du facteur de qualité de la structure. Cette nouvelle méthode, combinée à une amélioration du procédé de fabrication des CRIGFs, nous a permis d'exalter de manière importante la SHG dans une structure simplifiée.
Nous avons également effectué une première étude théorique de l'impact de l'accord de phase sur l'exaltation de la SHG dans les CRIGFs. Nous avons ainsi montré que l'accord de phase permettait de gagner plus d'un ordre de grandeur sur cette exaltation, en comparaison avec un CRIGF classique.
Pour finir, nous avons étudié théoriquement le comportement du CRIGF sous incidence oblique, en régime linéaire. Nous avons ainsi montré que cette configuration permettait de s'affranchir de la conception d'un anti-reflet. L'utilisation du CRIGF sous incidence oblique pourrait donc permettre d'inclure la conversion non-linéaire de fréquence dans une cavité externe de diode laser, tout en jouant le rôle de stabilisateur spectral pour cette diode.

Mots-clés : Génération de seconde harmonique, Nanophotonique, réseaux résonnants, optique non-linéaire, nanofabrication, RCWA

Abstract.

Title : Second harmonic generation in cavity resonator integrated grating filters.

Second harmonic generation (SHG) is a second order nonlinear optical process. It corresponds to the conversion of a wave at a fundamental frequency ω into a wave at frequency 2ω, when the fundamental wave interacts with a nonlinear medium. SHG can be used for a vast range of applications : data storage, biological imaging, quantum optics, laser sources, ... However, to obtain a high conversion efficiency, we need to fulfill specific experimental conditions. One key condition is to obtain the strongest pump field in the nonlinear medium. The recent development of nanophotonics allowed the creation of components that strongly enhance the local electric field. During this work, we studied field enhancement and SHG in a cavity resonator integrated grating filter (CRIGF). A CRIGF is a small aperture ($\simeq 20\lambda$) filter made of a short resonant grating integrated between two Bragg mirrors, onto a multilayer stack. The main interest of this filter is that it can support a high-quality-factor resonance, excited by a focalized beam. Conbining this tight focusing with high-quality-factor resonance results in a strong local field enhancement inside the CRIGF, which is particularly promising for SHG.
In this work, we present different nonlinear CRIGFs designed for improved conversion efficiency. First, we designed these structures like spectral filters. That means that we designed the multilayer stack to be anti-reflective around the pump wavelength. Second, we show that this anti-reflection condition is not necessary to improve the nonlinear interaction. We then develloped a new design method, based on the optimisation of the quality factor of the CRIGF. This new method, combined with an improved fabrication process, allowed us to strongly increase the SHG in a simpler structure. We also carried a first theoretical study of the effect of the phasematching condition on the conversion efficiency in a CRIGF. We show that the conversion efficiency is more than one order of magnitude higher when the phasematching condition is fulfilled. Finally, we studied theoretically the linear response of the CRIGF under oblique incidence. We show that this configuration can be used for applications where the anti-reflective condition is hard to achieve. This configuration could also be integrated in a external cavity laser diode, for intracavity wavelength conversion.

Keywords : Second harmonic generation, nanophotonics, resonant gratings, nonlinear optics, nanofabrication, RCWA

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