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Light Wave in a Photonic Crystal Waveguide

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Abstract—*The light matter interaction is an interest of topic for many years to the scientist and engineers. The light in dielectric structures can be studied such as ring resonators and photonics crystals. Slow light in photonic crystals have been studied by T.F.Krauss in [7].They have focused on the suitability of photonic crystals slow light waveguides for enhanced functional devices such as switches, optical delay lines and optical storage. Photonic crystals also offer waveguide flexibility.*

1. INTRODUCTION

Photonic crystals have inspired great interest recently because of their potential ability to control the propagation of light. Periodic dielectric structures with complete band gaps can find many applications in fabrication of lossless dielectric mirrors and resonant cavities for optical light. Photonic bandgap waveguides can efficiently guide light around corners. [1]

2. PHOTONICS CRYSTALS IN A WAVEGUIDE

.A key aspect offered by the photonic crystal system is that it offers a large bandwidth; this is critical for ultrashort optical pulses [2].Photonic crystals have two features (1) backscattering and (2) omnidirectional reflection. These two interactions generate forward and backward wave that create standing waves in optical crystal. Another thing that light propagated at an angle is propagated inside the waveguide [7].

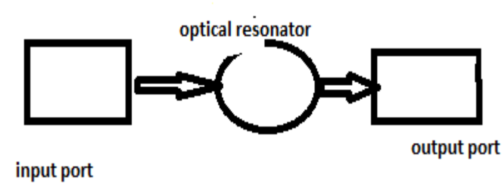
Photonic crystal also offer wavelength flexibility as their operating point is defined by the lattice constant.[2].An integrated on chip ring resonator on single crystal diamond on insulator substrate with wide band operation around 1550nm with quality factors as large as 15000 for TE and TM modes are introduced in [2].Diamond has gained a lot of interest in photonic research community due to exceptional physical chemical and optical properties and stable color centers. It has its high refractive index, transparency over wide wavelength range and large bandgap. Along with this large Raman gain, third order nonlinearity, make diamond ideal platform for the implementation of novel nonlinear photonic devices [2]. The difficulties also arise in achieving this crystal diamond films.

In the microwave ring resonator by choosing a waveguide with width=700nm and height=550nm efficient four wave mixing can be achieved [2].This experiment was operated at 1550nm.

2.1Optical bistability and Fabry Perot resonator

The optical bistability has been proved for Fabry Perot resonant cavity. [3]Bistability is achieved with switching process of 0.4mW with switching time of about 100ps [3].Micro cavities are particularly suitable for geometric enhancement of nonlinearities where all optical logic processing is not feasible [4]. In addition, optical bistability of Ph.C. micro cavities can be used as the basis of complex devices performing all optical logic operations. Importantly, due to their characteristic size, switching time and high integrability, this new class of optical processing devices have many of the features for their on chip implementation [4]. Rapid developments of experimental techniques, during the last decade has also been as important growth in the large scale computing technologies. Thus the combination of finite difference time domain method (FDTD) (which simulate Maxwell's equation with no approximations apart from discretization), coupled mode theory or perturbation theory [4] allow a complete characterization of electromagnetic response of the nonlinear Ph.C. (Photonic crystal) cavities under study.

Nonlinear optical process can be dramatically enhanced by Ph.C. resonators [4].



2.2 Silicon nanocrystals

Silicon can be used for nonlinear applications at 800nm both in the form of porous silicon or embedded in SiO2. [8] Optical nonlinearities in semiconductors are a combination of bounded electrons, free carriers and thermal effects. Experiments done that fs pulses produced by laser changed he refractive index [8].Experiments by R.Spano shows that Silicon rich oxide films were deposited by plasma enhanced chemical vapors deposition on quartz substrates using N_2O and SiH4.This experiment developed Silicon nanocrystals.

3. LIGHT MATTER INTERACTION

When light enters in a crystal known as a Kerr material it is polarized. The polarization equation is given by

$$\epsilon_0\chi^1_{ij} : E + \sum_i^3 \sum_j^3 \epsilon_0 \chi^2_{ijk} : EE + \sum_i^3 \sum_j^3 \sum_k^3 \chi^3_{ijk} : EEE + \cdots$$

Where E= E_0+ $E_w \cos wt$

And $\Delta n = \lambda_0 \mathrm{K} \left| E \right|^2$ defined by the change in the refractive index as Kerr constant of the medium[6].

Refractive index n=$(1+\chi)^{1/2}$=$(1+\chi_{lin}+\chi_{nonlin})^{1/2}$

The optical Kerr effect manifests itself as self-phase modulation and frequency shift of a pulse of light as it travels through the medium. For a Kerr nonlinear material the crystal resonator also exhibit bistability. For switching devices linear or nonlinear operates on the basis of relative phase changes. Overall nonlinear interaction benefits from phase change and refractive index change. Such change is found in the Kerr medium.

This process along with dispersion can produce optical soliton [5]. Using Kerr type material size of optical switch would drop from centimeters to hundreds of micrometers or the required switching power will be reduced by two orders of magnitude.[7]

3.1 Harmonic generation in photonic crystal cavities:

Optical nonlinearities are caused by atomic or molecular resonances. Nonlinear optical process lead to harmonic generation in which the light at one frequency w is converted to light at some multiple of this frequency. At χ^3 (Kerr) nonlinearity in which metal polarization has term E^3. That leads to generation of 3w from w. This process along with sum and difference frequency generation (χ^2) or four wave mixing χ^3 can be exploited for frequency conversion of signals and sources [5].

4. CONCLUSION

Hence slow light effects in photonic crystal waveguides are most advantageously deployed to enhance (a) linear effects such as electro optic and thermo optic effects (b)nonlinear effects such as Kerr based switching , Raman amplification and possibly parametric effects such as wavelength conversion .[7]

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