Trapping and storing light in $\chi^{(2)}$ photonic crystals

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Abstract

A study of parametric down-conversion in photonic crystals reveals that the probe field can be slowed down to 11m/s: i.e. a tunneling velocity previously reported only for coherently resonant interactions in Bose-Einstein condensates.

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Very recently, extremely small group velocities have been demonstrated for light pulses that propagate through certain materials [1-3]. The effect is sometimes referred to as light trapping. The process involves a resonant interaction between a control and a signal beam, tuned such that quantum coherence is established between an excited state and two nearly-degenerate ground states [3]. The signal beam then experiences an effective dispersion such that its group velocity becomes a minimum in a region of transparency (electromagnetic induced transparency, or EIT). The dispersion in that region of the spectrum is so steep that narrow-band pulses can propagate with extremely small group velocities.

In this work we show that light may also become localized and slowed down to velocities of only a few meters per second, and consequently stored, as a result of a parametric down-conversion process in a one-dimensional photonic crystal. Rather than relying on quantum mechanical interactions between atomic levels resonant with the incident light, the phenomenon that we describe occurs as a result of the confinement of light within a structure of finite length [4]. This process therefore begins purely as an interferometric phenomenon that manifests itself initially with the creation of classical Fabry-Perot-like transmission resonances . At this point we allow two quasi-monochromatic beams (or pulses whose frequency bandwidth is much narrower than resonance bandwidth), a fundamental frequency (FF) and a second harmonic (SH) field, to enter a $\chi^{(2)}$ photonic crystal, with the FF intensity assumed to be much weaker than the SH signal. Then, we take advantage of the enhancement of quadratic interactions due to the simultaneous availability of high field localization (i.e., feedback) and robust, exact phase matching conditions to amplify the weaker field. We note that the aspect of amplification has never been investigated in this context. As a result, the tunneling velocity of the FF pulse can slow down to just a few meters per second (see Fig.1). We note that the material that we consider contains a second order nonlinearity, and acts as a catalyst in that energy in never transferred to it; rather, it is always stored in the fields inside the structure.

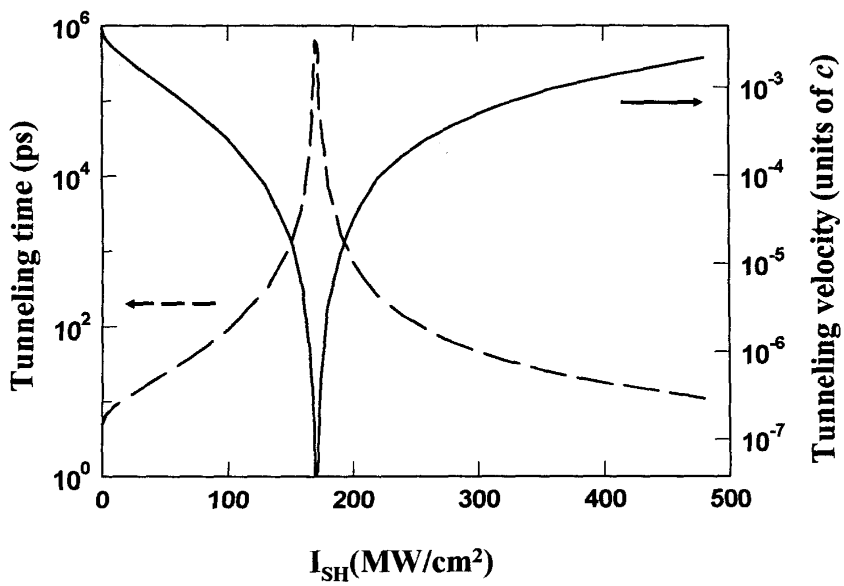

Fig.1. Tunneling time (dashed line) and tunneling velocity (solid line) of the FF transmitted field vs. the SH input intensity. The PBG structure is made by 59 alternating layers of air and a dielectric material. The index of refraction of the dielectric material at the FF (λ=1.55µm) is $n_1(\omega)$=3.342, and its index of refraction at the SH frequency is $n_1(2\omega)$=3.61. The layers have thicknesses a=90nm (air) and b=150nm (dielectric material), $d^{(2)} = 120\, pm/V$.

References

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