

Recent Progress in Photonic Crystal Devices

(Toshihiko Baba)

Abstract :

Photonic crystals (PCs), multi-dimensional mosaic structures with a period of the order of optical wavelength, have provided various recent topics on photonics such as nanolasers, slow light and negative refraction. This presentation reports some recent progress on PC devices based on a PC slab, a high-index membrane with 2D airholes.

The PC nanolaser consists of a defect in a PC slab. It is expected to be a high efficiency light source with controlled spontaneous emission. Key issues are the ultrasmall modal volume V_m and high Q . We employ a point-shift nanocavity, whose V_m is as small as $2(\lambda/2n)^3$. In a GaInAsP QW device, the room temperature cw lasing is obtained by photopumping with a 1.2 μ W threshold, 50 dB peak intensity and < 20 pm linewidth. For this cavity, a 100 ps order fast spontaneous emission lifetime is obtained due to the Purcell effect. In photonic integrated circuits, it must be integrated with passive components. Such integration is succeeded by using MOCVD buttjoint regrowth technique. A 100 μ W class output power and more than 20% external efficiency are now available. Also, sensing applications to bio-molecules are expected with the narrow linewidth.

Slow light in a SOI PC line defect waveguide is a feasible solution for optical buffering and signal processing with enhanced light-matter interaction. However, a narrow bandwidth and large group velocity dispersion (GVD) usually disturb its practical use. To eliminate these problems, we have proposed two types of slow light, i.e. dispersion-compensated slow light in a chirped PC directional coupler or coupled waveguides and zero-dispersion slow light in modified PC waveguide exhibiting a straight photonic band. Both of them achieve dispersion-free light propagation for sub-ps optical pulses with a group index of 30 – 60 and a wavelength bandwidth of 30 – 10 nm. The enhancement of optical nonlinearity is also observed particularly in the zero-dispersion slow light, compressing optical pulses in space.

The negative refraction arising from the multi-dimensional dispersion characteristics allows unique focusing and beam steering of light. The focusing of light at a flat surface, parallel image formation, superprism effect, and wavelength demultiplexing operation can be observed at near infrared wavelengths in a SOI PC slab having optimized interfaces, which greatly improves the matching of incident wave with internal Bloch waves.

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