What is ‘Photonic Band Gap’ (PBG) and ‘Photonic Crystal’?

The concept of ‘Band gap’ represents a forbidden region in a material which must be crossed by the quantum particles to attain a different level of activity or potential. This concept is well known in the case of electronic energy levels as applicable to insulators, semiconductors and metals where the electron band gap progressively diminishes. This band gap represents quantized gap for electronic energy transition.

‘Photonic band gap’ (PBG) is a term applicable to dielectric media which possess alternate regions of low and high refractive index such that transmission of ‘photons’ or light energy of certain frequencies is forbidden. Thus it is a photon forbidden region analogous to electron forbidden region in the case of electron band gap of semiconductors.

Phenomenon of photonic band gap was discovered in early nineties. In more scientific terms, the phenomenon is also referred to as ‘Photon localization’ since the photons of certain wavelength appear to be immobilized in the materials with photonic band gap. This phenomenon is frequency dependent and hence gives rise to a play of colors like in naturally occurring gemstone ‘opal’. The materials exhibiting photonic band gap are known as ‘Photonic crystals’. These materials are said to possess capability to ‘mould’ light as required.

The mechanism behind localization of photon consists of:

- Spatial periodicity of optically dense and rare domains.
- Dimension of individual domain of the order of wavelength of light
- High contrast of refractive indices between the alternate domains (of the order of 2.5~3.0). Hence the air can be one of the domains.
- Pronounced back scatter followed by interference produces the resultant frequencies or ‘colors’.

These domains can be one, two or three dimensional. Three dimensional photonic crystals are the true photonic band gap materials as these would exhibit photon localization in any direction. Such materials are very difficult to fabricate.

Following are the techniques used to build PBG materials:

- Layer by layer nanofabrication
- X-ray lithography
- Laser holography
- Use of di-block copolymers
- Colloidal self assembly
- Thin film coatings

Materials with 1D photonic band gap are already in use in the form of thin films like colour changing pigments. Applications of 2D photonic crystals are emerging in the area of communication through photonic crystal fibers. 3D photonic dielectrics are an area of intense research and such materials will find applications in optical computers. (See Figure)

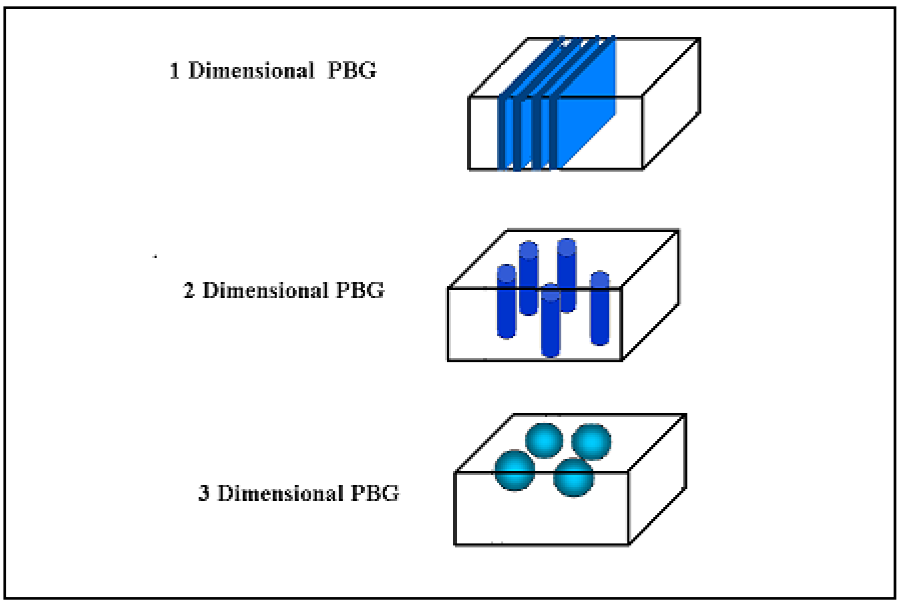

Fig: Photonic Band Gap 1D, 2D & 3D