# Resonant photonic crystals and quasicrystals

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A periodic structure is called the *resonant photonic crystal* if (a) it forms a grating for the Bragg diffraction of light and (b) the dielectric response of at least one of its composite materials as a function of the frequency has a pole. In such systems the normal light waves are polaritons. Similarly one can define *resonant photonic quasicrystals* and other aperiodic deterministic sequences. Multiple quantum wells (MQWs) are ideal model systems for one-dimensional photonic crystals and quasicrystals. In this lecture we discuss the exciton polaritons and optical properties of periodic and aperiodic quantum-well (QW) structures.

Among long-period QW structures, of particular interest are the resonant Bragg structures or resonant Bragg refectors with the period $d$ satisfying the Bragg condition, $q(\omega_0)d = \pi$, at the exciton resonance frequency $\omega_0$. Depending on the number of wells $N$ they reveal either the superradiant regime or the photonic crystal regime. In the former case both the amplitude and the halfwidth of reflection spectral peak are enhanced by a factor of $N$, while in the latter the structure has a well pronounced stop-band. The similar resonant Bragg condition for the quasiperiodic Fibonacci MQWs has the form $q(\omega_0) = G_{hh'}/2$, where $G_{hh'} = (2\pi/d)(h + h'/\tau)$ is the diffraction vector with the integers $h$, $h'$ equal to two successive Fibonacci numbers ($d$ is the average inter-well distance). The Fibonacci MQW structure tuned to this condition also exhibits both the superradiance and photonic stop-band with the following important difference: (i) for a small number of wells, the superradiant reflection peak has a remarkable structured dip in the middle, and (ii) at large $N$, a single stop-band is replaced by two equivalent stop-bands separated by an allowed exciton-polariton band. Linear and nonlinear reflectivity spectra measured from high-quality GaAs/AlGaAs QWs with spacings satisfying a Fibonacci sequence are in good agreement with excitonic polariton theory.

In the lecture, emphasis is placed on similarities and differences between optical properties of the quasicrystals, being the third form of solid matter, and those of conventional crystals and amorphous materials. Similarly to periodic systems, the two-wave approximation is often efficient to describe, within narrow frequency intervals, the light propagation in a quasicrystalline medium. Moreover, sometimes it is even instructive to introduce effective allowed bands and forbidden gaps (or stop-bands) for light waves propagating in such medium. The resemblance to disordered materials reveals in properties of photonic crystalline approximants of quasicrystals. With increasing the thickness of the approximant supercell, the optical spectra provide an evidence for the localization of light waves. Important specific features of the photonic quasicrystals with small values of the exciton nonradiative damping rate are a scaling and self-similarity of optical spectra which are completely absent in crystalline and amorphous materials.