Super-bound states in the continuum in periodic slabs

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Bound states in the continuums (BICs) have found important applications in photonics. In dielectric structures with a 1D periodicity, a BIC is associated with a real frequency ω_* and a real Bloch wavenumber β_*. For any real β near β_*, there is always a resonant mode with a complex ω and a quality factor $Q \sim 1/|\beta - \beta_*|^m$. Usually, $m = 2$. If $m \geq 4$, the BIC is a super-BIC [1]. Super-BICs are particularly attractive for applications.

In a 2D structure that is invariant in x, periodic in y, bounded in z, and surrounded by air, a TE polarized BIC has the electric field component $E_x = e^{i\beta_* y}\phi(y, z)$, where ϕ is periodic in y and tends to zero as $z \to \pm\infty$, and $\omega_*/c > |\beta_*|$. For a simple grating with each period consisting of two segments, we have found eight different types of BICs listed in the table below, where NZ means

BIC type	1	2	3	4	5	6	7	8
β_*	0	NZ	0	NZ	0	NZ	0	0
symmetry in y	odd	PT	even	PT	odd	PT	even	odd
m	2	2	4	4	6	6	8	10
N	0	0	1	1	1	2	2	2

$\beta_* \neq 0$, odd, even and PT mean $\phi(-y, z) = -\phi(y, z)$, $\phi(-y, z) = \phi(y, z)$ and $\overline{\phi}(y, z) = \phi(-y, z)$, respectively, m is the power in the asymptotic relation of Q, N is the number of structural parameters needed to find the BIC. If $N = 1$, the BIC exists as a curve in the plane of two parameters. If $N = 2$, the BIC corresponds to a single point in the plane of two parameters, and a curve in the space of three parameters. BICs of type 1 and 2 are robust, since they exist without the need to tune any parameter. Super-BICs with $m \geq 4$ can only be found by tuning at least one parameters (i.e. $N \geq 1$). A theory is developed to reveal the number N for different kinds of BICs. An efficient numerical method is developed to find the super-BICs with $m \geq 4$ and $N \geq 1$ efficiently.

In summary, a comprehensive theory and an efficient computational method for super-BICs in dielectric structures with a 1D periodicity are developed, and numerical results for a simple 1D grating are presented.

References

[1] N. Zhang, Y. Y. Lu, *Perturbation theory for resonant states near a bound state in the continuum*, Physical Review Letters **134**, 013803 (2025).