# A Specialty Optical Fiber to Host Optical Bound State in the Continuum

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## 1. Introduction

Optical Bound states in the continuum (BIC) are localized states embedded in the continuum with no leakage radiation. The formations of these localized states is similar to the Anderson localization phenomenon. These BICs form only after precise destructive interference between scattered waves of the embedded states. In recent times, the realization and implementation of BICs in photonic systems has been an area of extensive research due to its varied potential applications in the field of nonlinear optics [1], lasing [2] to name a few. Typical BIC physics under a strong coupling regime between resonant states in optical resonators has been reported. However, practical implementation of BIC driven schemes in other material optical devices such as fiber based systems are yet to be explored. In this context, we propose that a specialty optical fiber with multiple cores, in the presence of carefully tuned physical parameters of the system can host optical quasi-BICs. Exploiting the coupling between different cores in the system, we effectively negate the losses of higher-order modes to eventually attain a very high-$Q$ (Quality factor). These higher-order hybrid modes BIC-driven exhibit a boost in modal effective area.

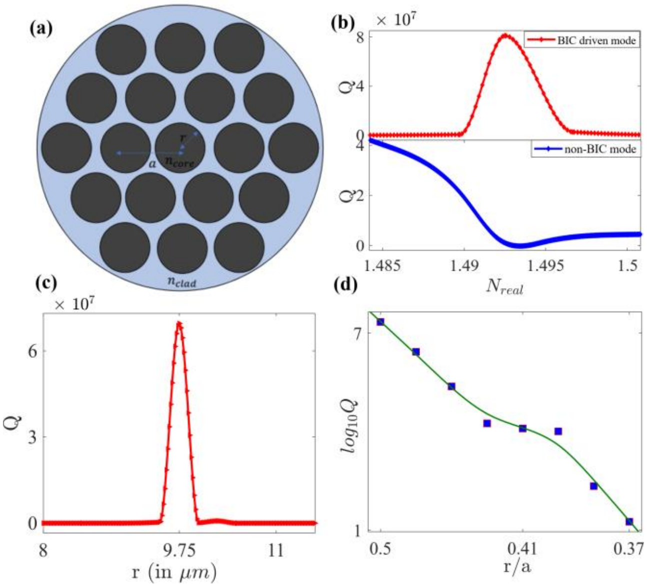

**Fig1: (a)** Schematic representation of specialty optical fiber with 19 high index cores. Here the radius of each core is $r$ and the core pitch is $a$. **(b)** The lateral quality factor $Q$ as a function of $n_{eff}$. **(c)** Variation of $Q$ as a function of $r$. **(d)** The curve fit plot of logarithmic variation of $Q$ as a function of the aspect ratio.

## 2. Design and Results

To fulfil our purpose, we design a specialty optical fiber with 19 cores, where we set the refractive index of the core as $n_{core} = 1.5$ and clad as $n_{clad} = 1.46$ as can be seen in fig.1(a). Here we introduce two tunable parameters, the radius of the cores ($r$) and the core pitch ($a$). We try to fix the overall radius of the fiber to $62.5\mu m$ for the sake of simplicity of the optimization. Furthermore, we define a parameter lateral quality factor a mode as $Q = \frac{Re[n_{eff}]}{2Im[n_{eff}]}$, where $n_{eff}$ is the effective refractive index of the mode. The parameter $Q$ captures the lifetime of a particular which near a BIC, should diverge to very large quantity. This occurs when the $Im[n_{eff}]$ vanishes, effectively nullifying the radiation channels of the mode. We further identify a higher mode following the same condition for $r = 10\mu m$ and $a = 20\mu m$ as can be seen in fig. 1(b). Subsequently we identify another mode at the same location in the parameter space undergoing a decay and after the couple leads to mutual energy exchange between the modes. We fine tune the couple using the parameters $r$ and $a$ using interactive optimization of the parameter. Accordingly, after sufficient iterations and negligible iterative error, the condition of $r = 9.75\mu m$ and $a = 2r$ (shown in fig. 1(c) and 1(d)) gives a maximum $Q$ for the given mode. Since the concept of continuous parameter tuning is similar to the Friedrich-Wingten type BICs, we denote this point as the quasi-BIC in the parameter space. At this quasi-BIC, the lifetime of the mode is found to be $Q = 6.9 \times 10^7$, which is 7 orders of magnitude more than the decaying counterpart. Successively, the effective modal area of the quasi-BIC mode was found to be $A_{eff} = 3216\mu m^2$, which was more than 2 orders of magnitude higher than the other modes.

## 3. Conclusions

In summary, we propose a scheme where we design a specialty optical fiber with multiple cores to host a quasi-BIC mode. Through careful system parameter tuning we report that a higher order mode having a very high effective area attains a higher lifetime. We report that the formation of a quasi-BIC would lead to the boost in the effective modal area upto two orders of magnitude even for a higher order mode. These results would open up a new potential for the design and development of low-threshold lasers and high performing optical sensors. Further report on modal and field analysis will be reported at the conference.

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## References

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