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*Publication date:*
2015

*Document Version*
Publisher's PDF, also known as Version of record



*Citation (APA):*
Østerkryger, A. D., de Lasson, J. R., Yu, Y., Mørk, J., & Gregersen, N. (2015). *Investigations on the parity of Fano resonances in photonic crystals*. Poster session presented at CLEO/Europe - EQEC 2015, Munich, Germany.

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# Investigations on the parity of Fano resonances in photonic crystals

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## I. Why Photonic crystal Fano structures?

- **Photonic crystals (PhCs) have potential applications within integrated photonics.**
- **Highly nonlinear resonant behavior makes Fano structures suitable for photonic switching in integrated circuits [1] and recently a PhC Fano laser has been proposed [2].**

## II. What is a PhC Fano structure?

- Fano = narrow Lorentzian field + broad background field

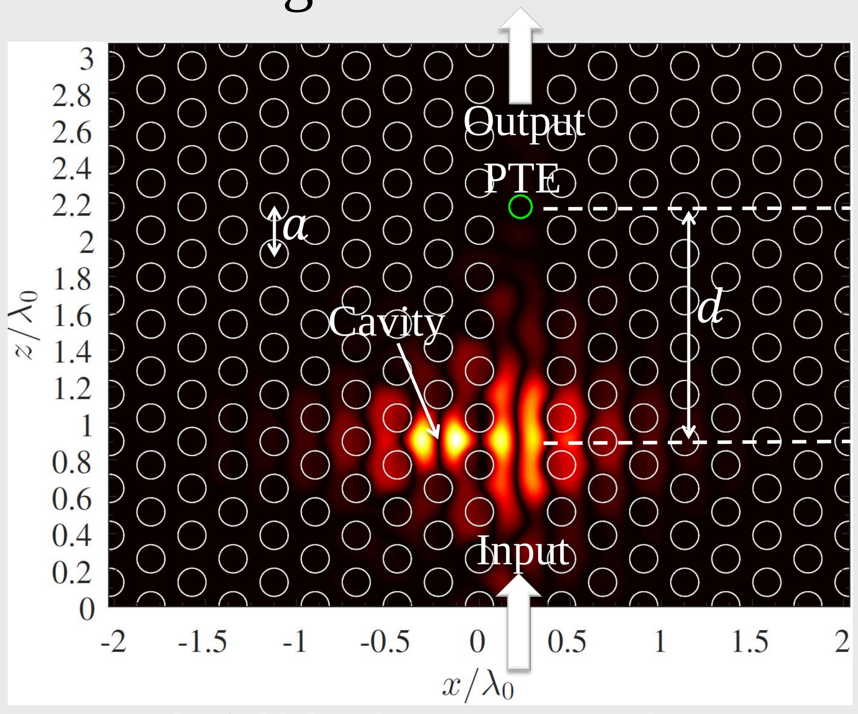


Figure 1: The field distribution ($H_y$) in a PhC Fano structure at the zero transmission point in Figure 4.

- Two different parities of transmission spectrum: red and blue parity.

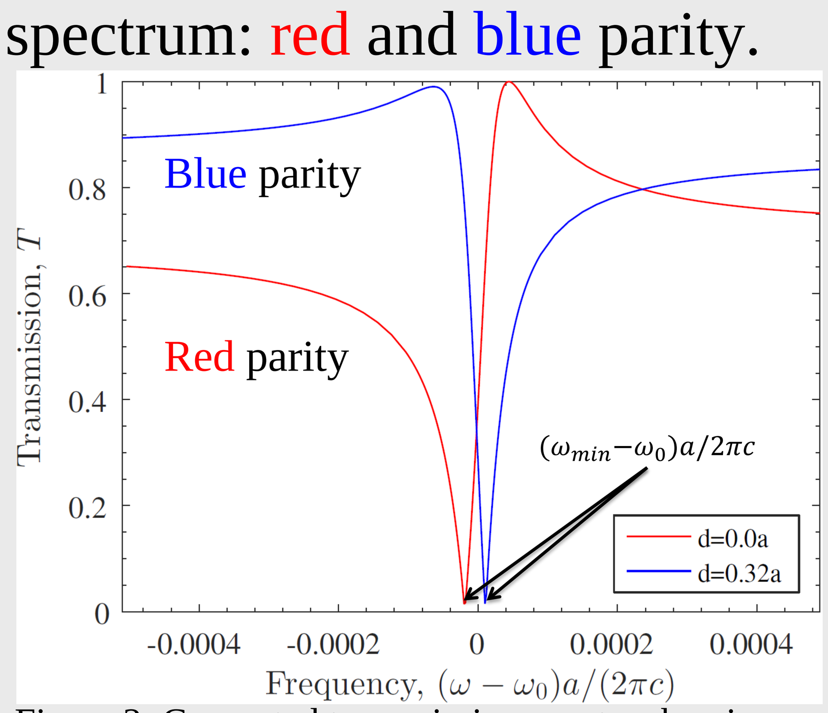


Figure 2: Computed transmission spectra showing the two different parities.

- **<u>What determines parity in PhC Fano structures is not well understood.</u>**
- Degree of parity, $DoP$, defined as slope before minus slope after $\omega_{min}$:

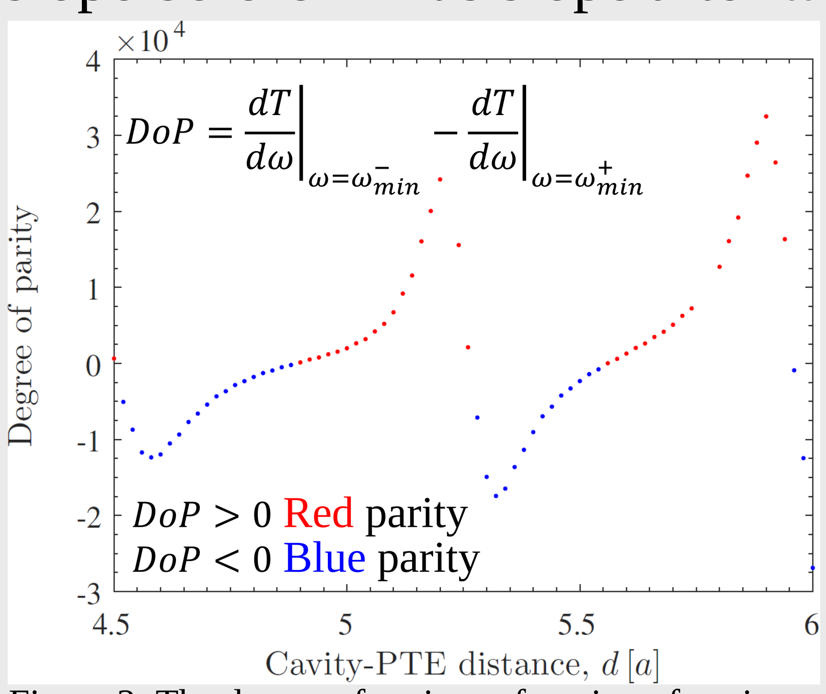


Figure 3: The degree of parity as function of cavity-PTE distance.

## III. Explanation of Fano parity in Fabry-Perot limit, $d/a \gtrsim 4.5$

- Single-mode description is sufficient when the cavity-PTE distance, $d$, is at least 4-5 unit cells.
- Transmission equation becomes scalar, since all other modes are extinct:

$$T = T_{PTE}P^{+}(1-RT)^{-1}T_{cav} \quad (1)$$
$$RT = R_{cav}P^{-}R_{PTE}P^{+} \quad (2)$$

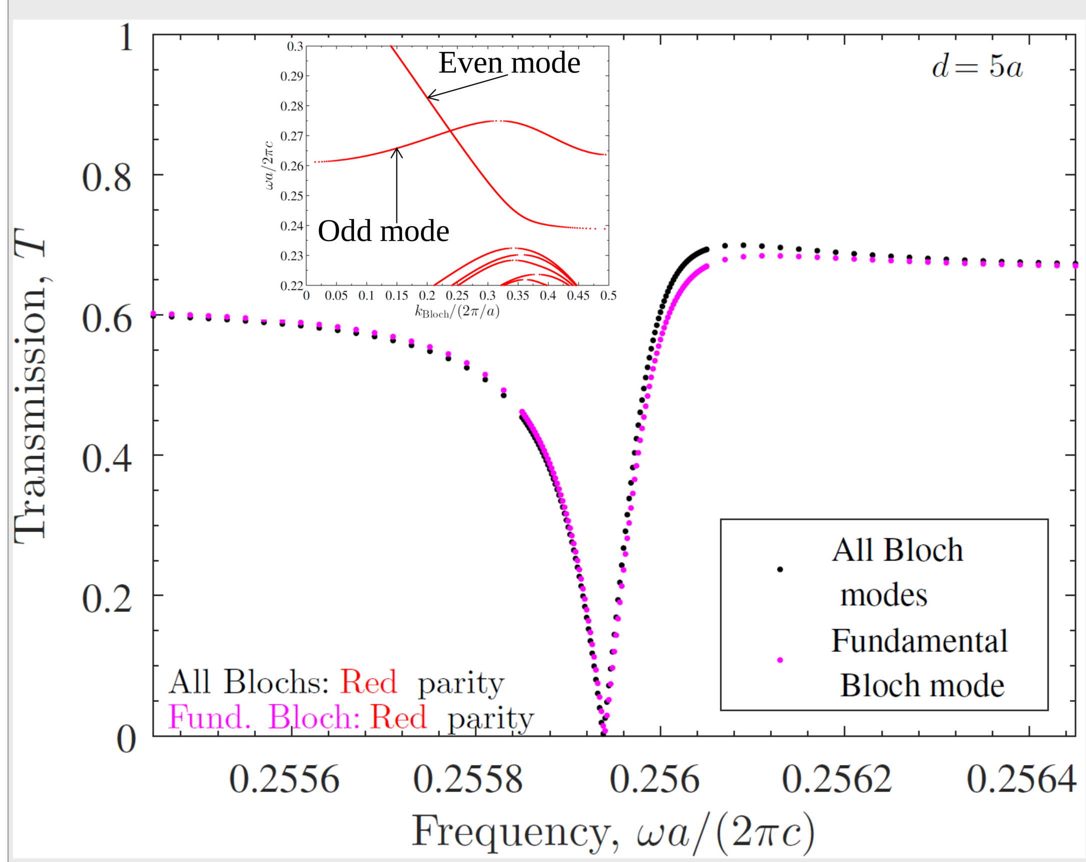


Figure 4: Transmission of PhC Fano structure computed using all Bloch modes (black dots) and only propagating Bloch mode (purple dots) inside the Fabry-Perot cavity. The inset shows the dispersion diagram for the PhC waveguide structure in the bandgap region.

- Phase of $RT$ at $\omega_{min}$ determines parity as seen in Figure 5.

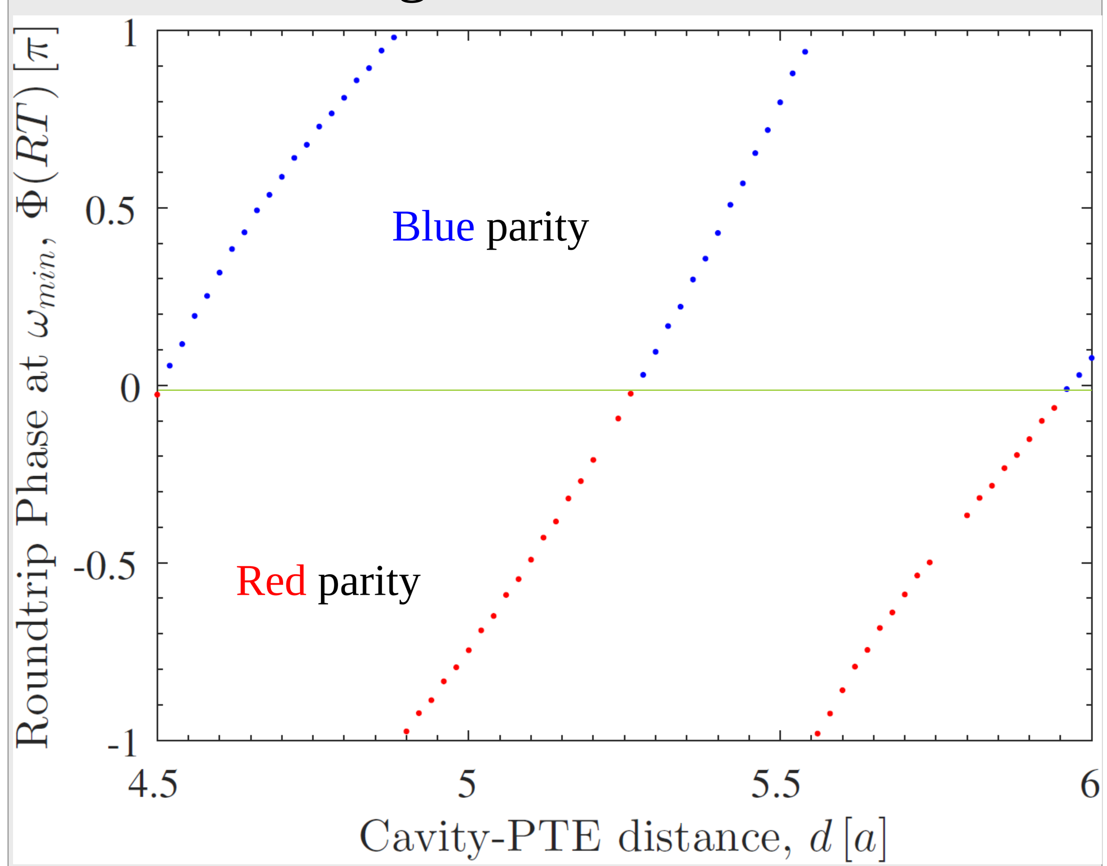


Figure 5: Phase of one roundtrip for different cavity-PTE distances.

## IV. Experimental observation of Fano parity shifts

- SEM image of PhC Fano structure:

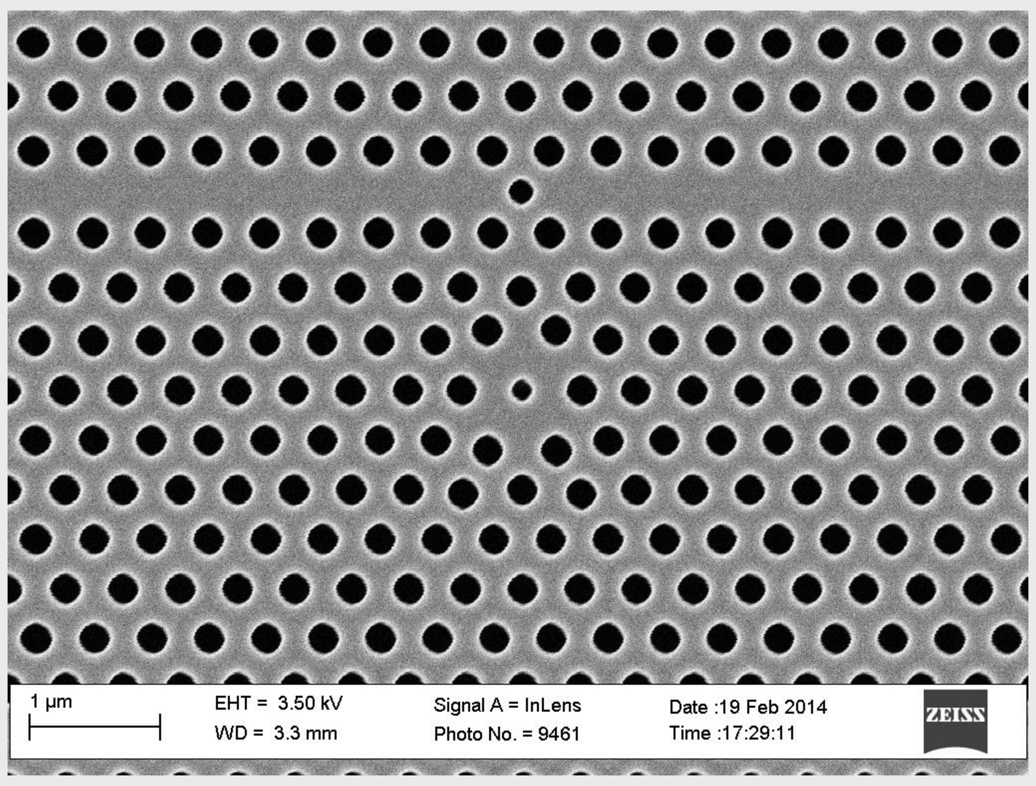


Figure 6: SEM image of InP PhC Fano structure with $a = 447$ nm.

- Change in parity of transmission spectrum is observed for different positions of PTE.

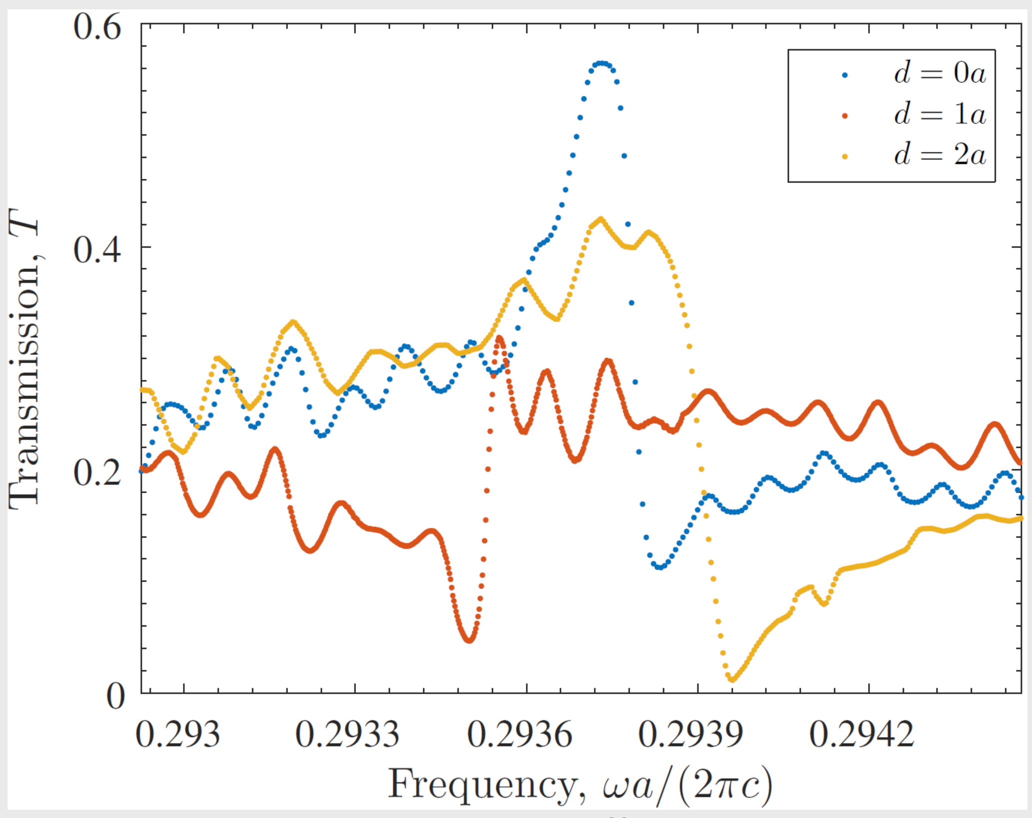


Figure 7: Experimental data on three different cavity-PTE distances.

## V. Conclusion

- The parity of a Fano transmission spectrum depends on the position of the PTE relative to the cavity.
- The phase shift obtained in completing one roundtrip in the Fabry-Perot cavity determines the parity in the Fabry-Perot limit.
- Experimental results have confirmed the dependence of parity on the position of the PTE.

[1] Y. Yu, M. Heuck, H. Hu, W. Xue, C. Peucheret, Y. Chen, L. K. Oxenløwe, K. Yvind and J. Mørk, "Fano resonance control in a photonic crystal structure and its application to ultrafast switching", Appl. Phys. Lett. **105**, (2014)
[2] J. Mork, Y. Chen, and M. Heuck, "Photonic crystal fano laser: Terahertz modulation and ultrashort pulse generation," Phys. Rev. Lett. **113** (2014)