

RF Electric Field Measurement with Electro-Optic Sensor

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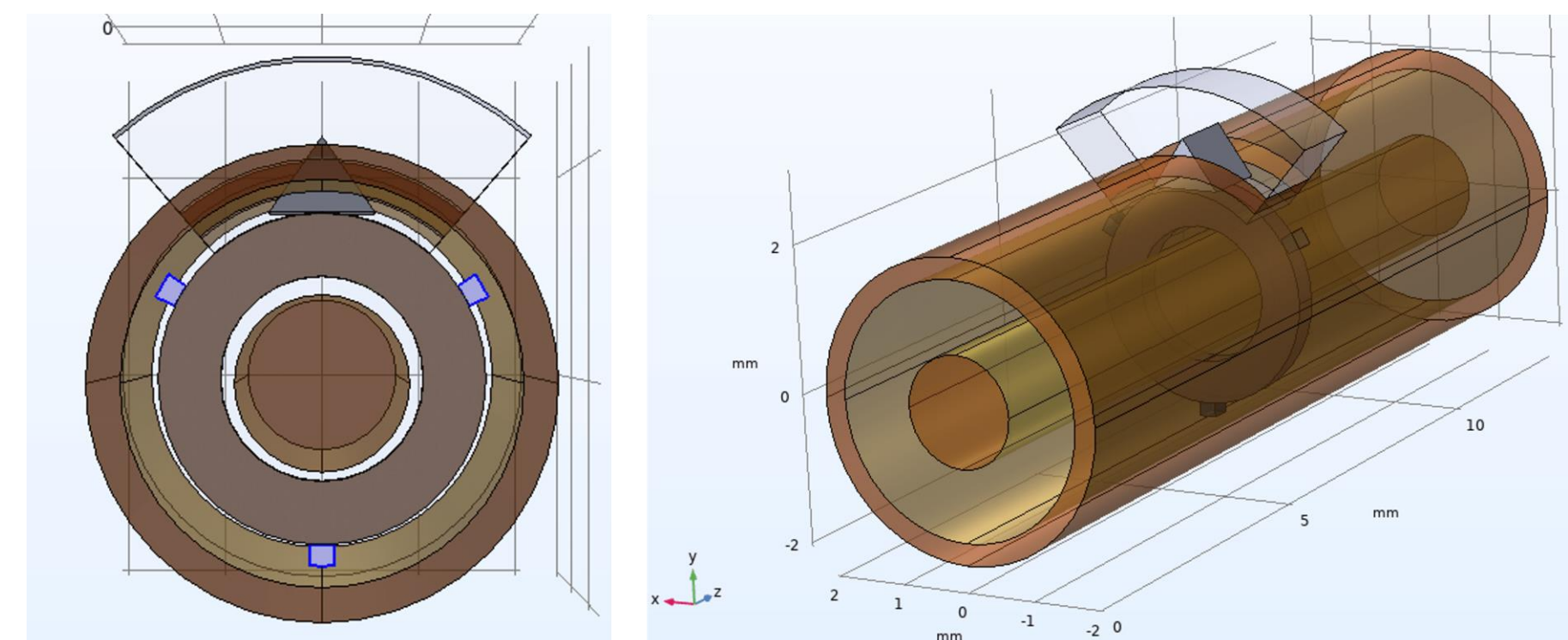
We present a novel RF electric field measurement device leveraging the electro-optic (EO) effect in advanced whispering-gallery-mode resonators (WGMR). Our sensor [1,2], made from Lithium Niobate (LiNO₃) and fabricated into a disk with a polished rim, shows potential for highly accurate, frequency-tunable, and ultra-fast RF electric field measurements with an extended linear dynamic range. We characterize the sensor's optical properties and demonstrate preliminary electro-optic measurements across different RF frequencies. Additionally, we outline calibration procedures [3] for our sensors using a proposed integrated coaxial structure, ensuring traceability through comparisons with RF calorimeters and directional couplers based on electromagnetic coupling. This technology holds significant promise for both metrological and industrial applications.

Characterization of Whispering-Gallery-Mode Resonators

- Physical parameters:** R = 2.5 mm, z-cut LiNO₃, disk-shaped, rim fabricated by high-precision diamond turning and polishing.
- Working principle:** Total internal reflection confines light within crystal, generating enhanced resonance ($Q > 10^8$).
- Coupling method:** Evanescent field coupling of a Gaussian mode with a position tunable prism (fine step: sub-nm).
- Abbreviations:** ECDL: external cavity diode laser; EOM: electro-optical modulator; FOC: fiber optic coupler; FP cavity: Fabry-Pérot cavity; FPC: fiber polarization controller; GRIN: gradient-index; PD: photo detector; DSO: digital storage oscilloscope; AMP: amplifier.

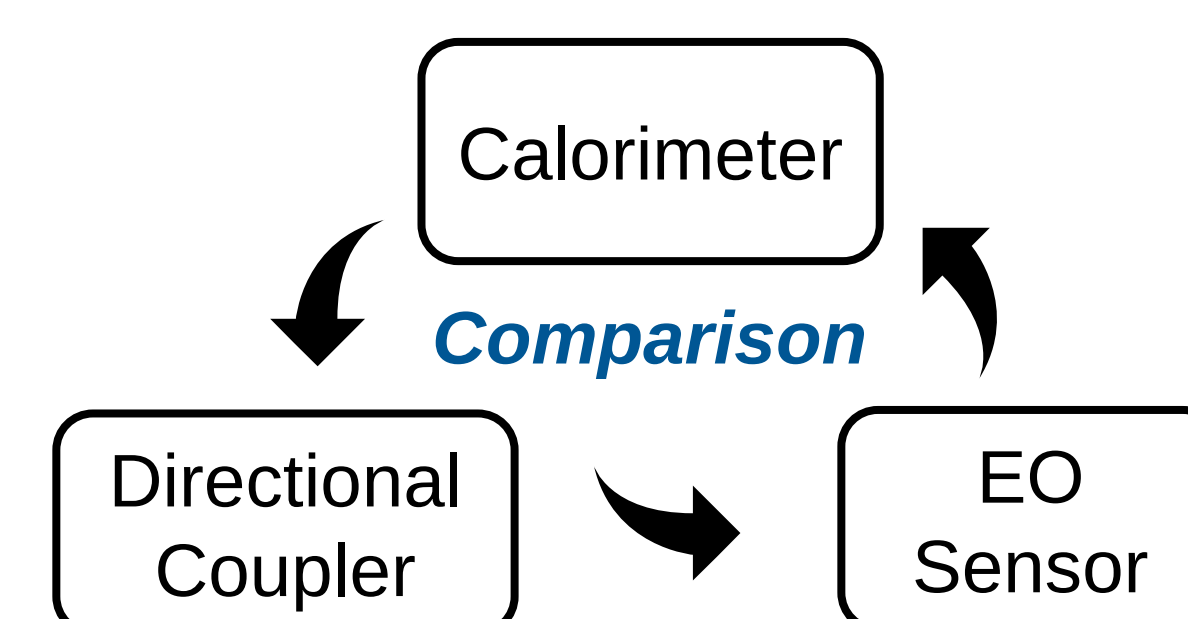
Preliminary Measurements for the Electro-Optic Effects

- EO effect:** The refractive index changes according to the EO coefficient (r) and RF electric field strength, leading to spectrum modifications.
- RF frequency $\leq$ linewidth:** The resonant signal splits under a time-averaged measurement.
- RF frequency $>$ linewidth:** Sidebands appear at the applied RF frequency.



Coaxial EO Sensor and Calibration Routine

- Ring shape:** Optical modes get sparse.
- Coaxial structure:** S-parameters can be easily calibrated; Electrical field mode distribution is precisely known.
- Calibration factor:** EO coefficients and geometrical dimensions must be accurately characterized.



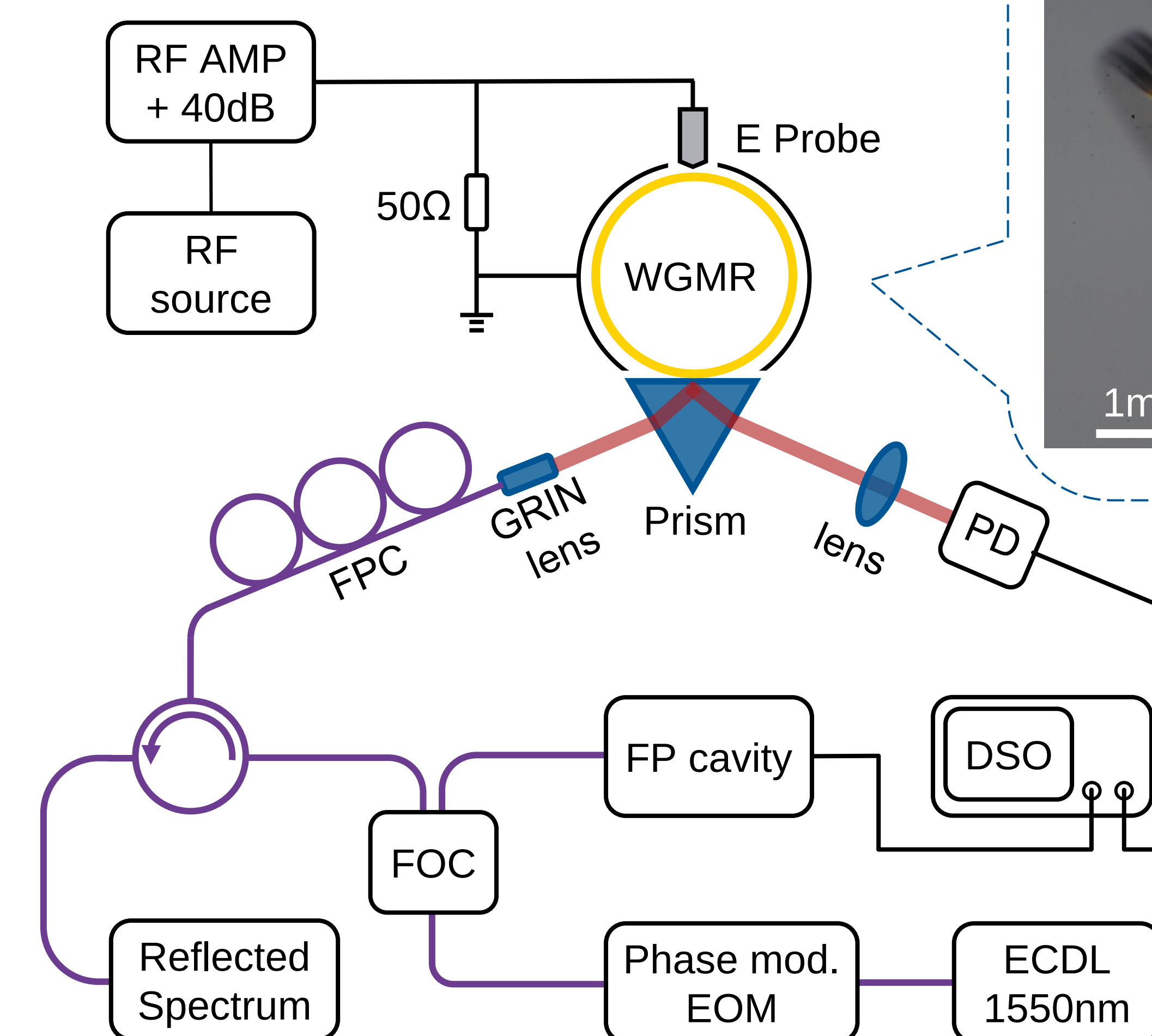
Traceability Comparisons

- Characterization of the calorimeter.**
- Comparisons:** Integration of EO sensors, calorimeter and directional coupler represent a comprehensive approach for RF measurement.

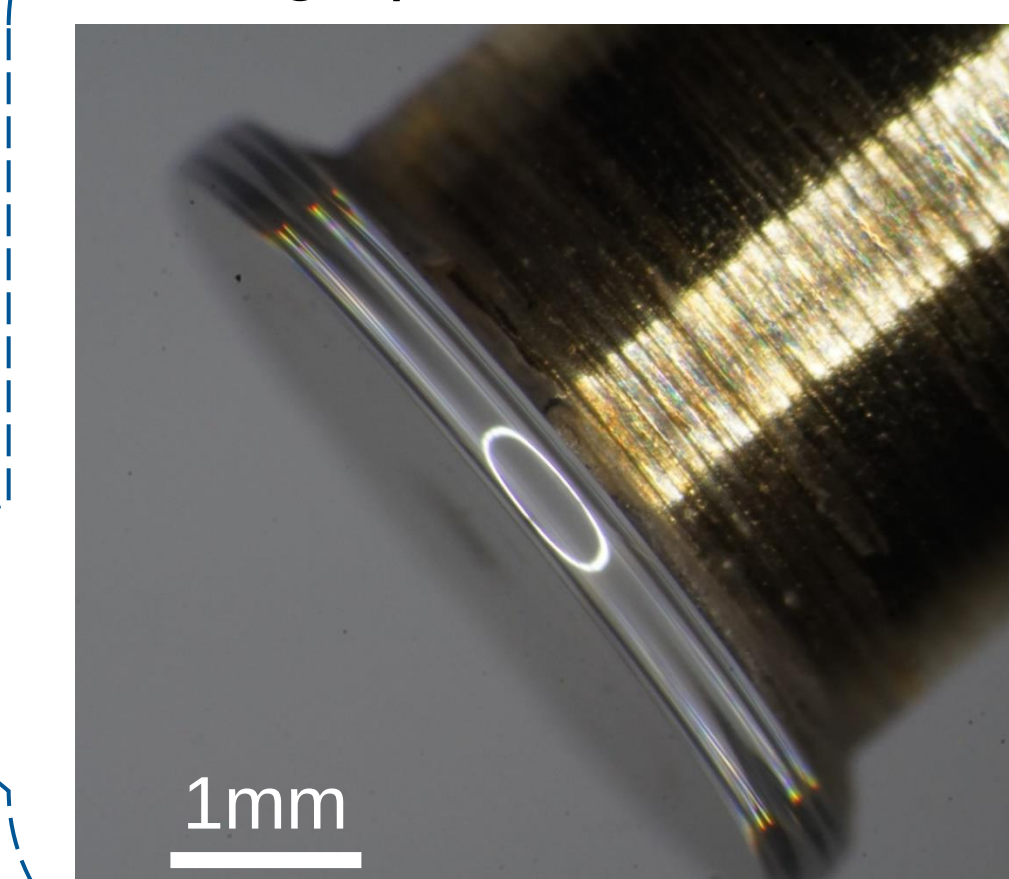
References

- [1] Strelakov, D. V., Marquardt, C., Matsko, A. B., Schwefel, H. G., & Leuchs, G. (2016). Nonlinear and quantum optics with whispering gallery resonators. *Journal of Optics*, 18(12), 123002.
- [2] Rueda, A., Sedlmeir, F., Kumari, M., Leuchs, G., & Schwefel, H. G. (2019). Resonant electro-optic frequency comb. *Nature*, 568(7752), 378-381.
- [3] Hoffmann, J., Stalder, D., Morel, J., & Zeier, M. (2018, July). Towards High Frequency Power Measurement Using the Electro-Optical Effect. In 2018 Conference on Precision Electromagnetic Measurements (CPEM 2018) (pp. 1-2). IEEE.

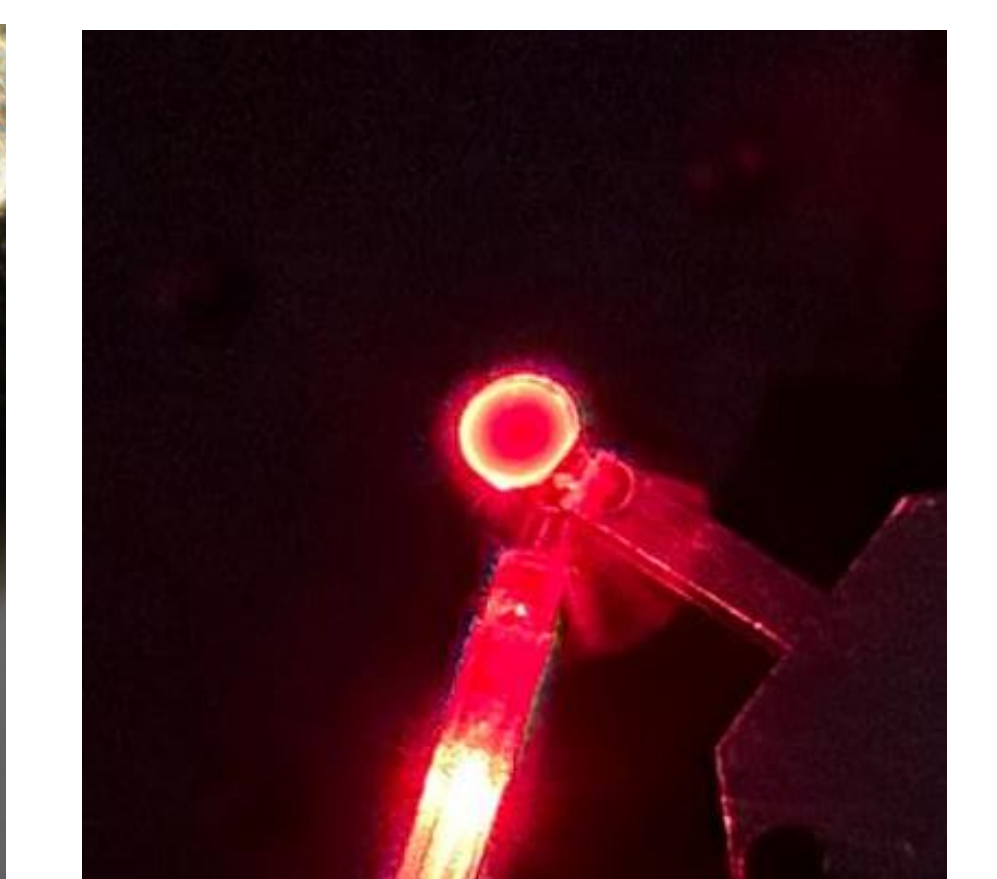
Experimental setup and WGMR



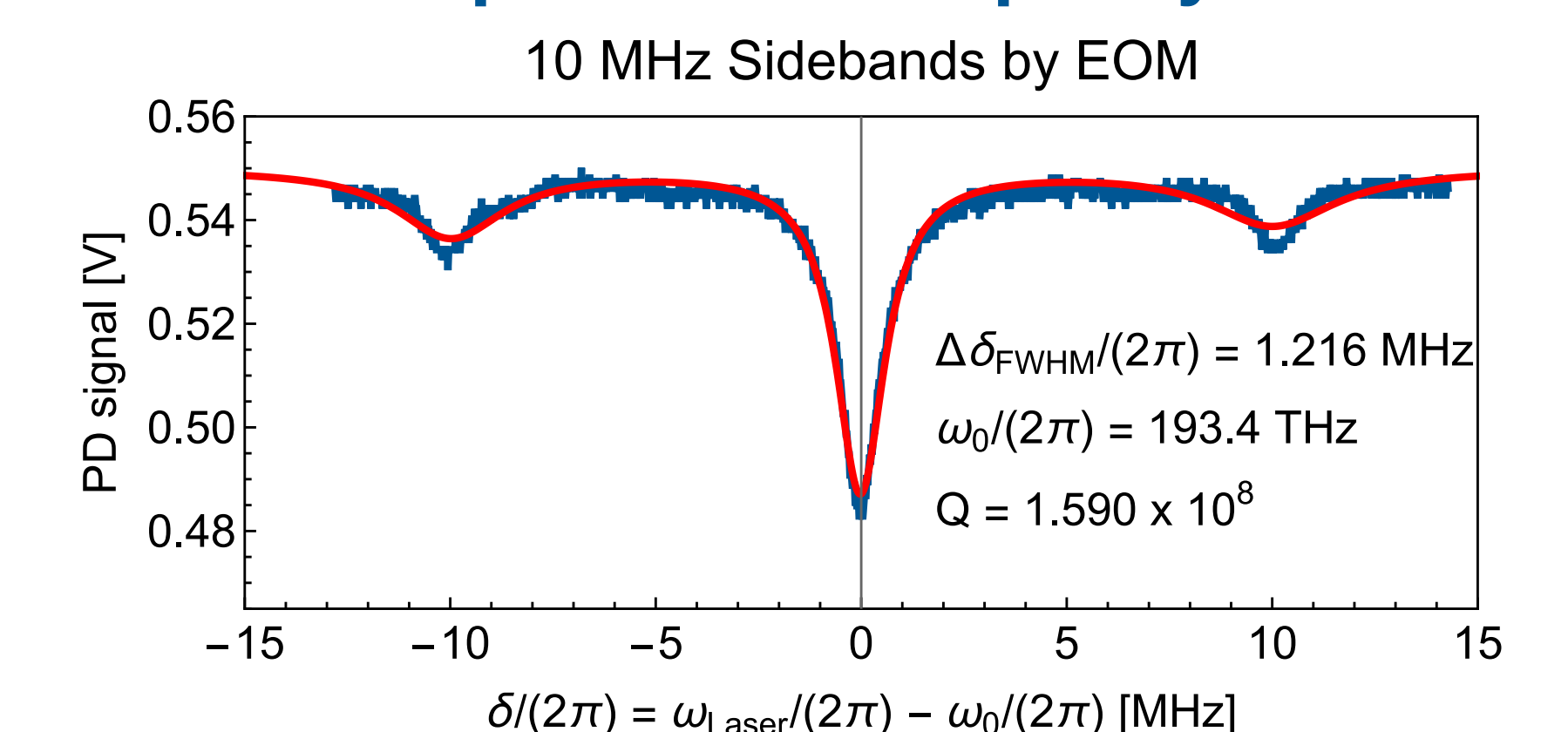
Micrograph of the WGMR



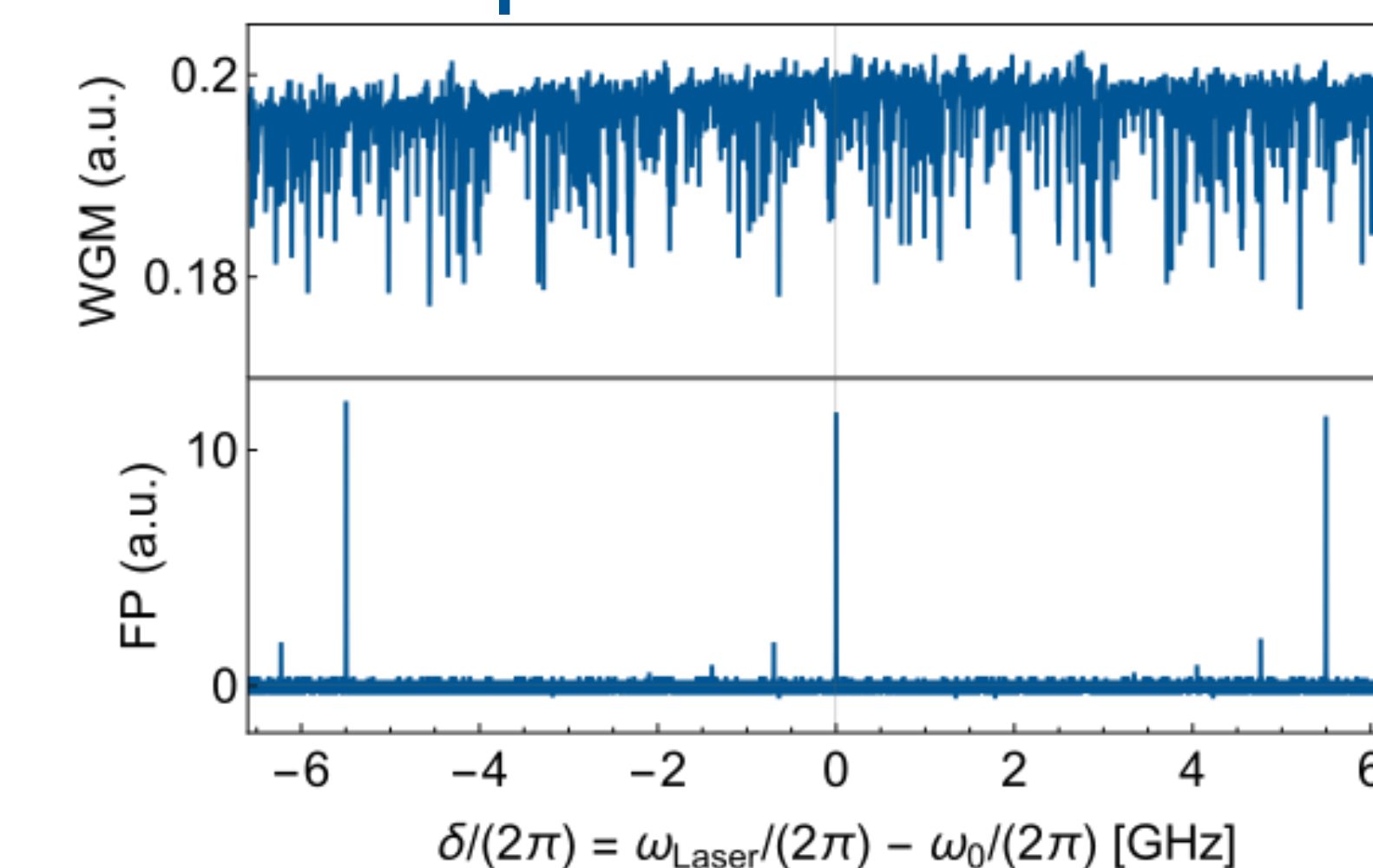
Confining light in the WGMR



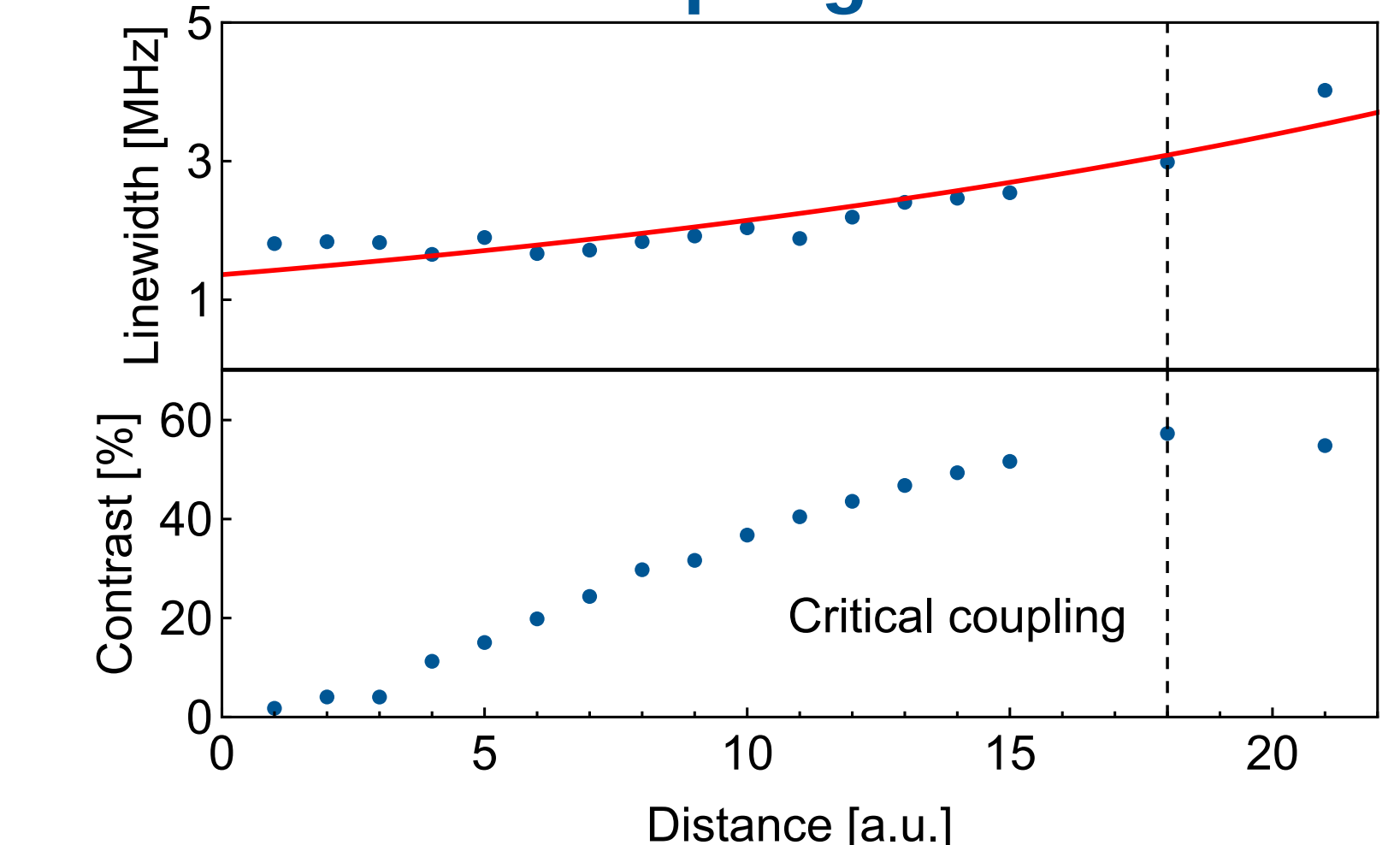
Narrow spectrum and quality factor



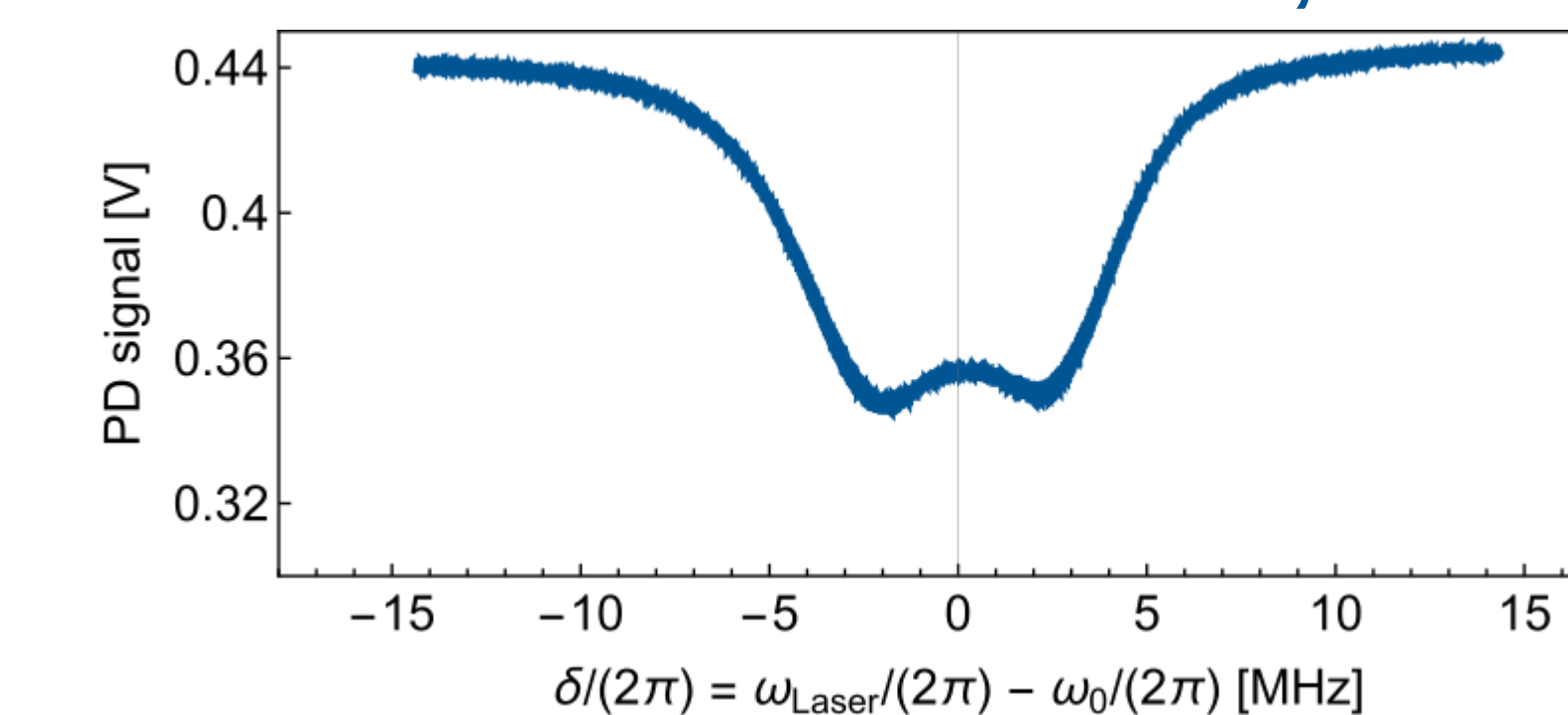
Wide spectrum



Different coupling conditions



EO effect with 1 MHz RF, -9dBm



EO effect with 7 MHz RF, -9dBm

