Using Whispering-Gallery-Mode Resonators for Refractometry

Refractive and absorptive properties are inferred by correlating predictions with measurements.

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A method of determining the refractive and absorptive properties of optically transparent materials involves a combination of theoretical and experimental analysis of electromagnetic responses of whispering-gallery-mode (WGM) resonator disks made of those materials. The method was conceived especially for use in studying transparent photorefractive materials, for which purpose this method affords unprecedented levels of sensitivity and accuracy. The method is expected to be particularly useful for measuring temporally varying refractive and absorptive properties of photorefractive materials at infrared wavelengths. Still more particularly, the method is expected to be useful for measuring drifts in these properties that are so slow that, heretofore, the properties were assumed to be constant.

The basic idea of the method is to attempt to infer values of the photorefractive properties of a material by seeking to match (1) theoretical predictions of the spectral responses (or selected features thereof) of a WGM of known dimensions made of the material with (2) the actual spectral responses (or selected features thereof). Spectral features that are useful for this purpose include resonances frequencies, free spectral ranges (differences between resonance frequencies of adjacent modes), and resonance quality factors (Q values).

The method has been demonstrated in several experiments, one of which was performed on a WGM resonator made from a disk of LiNbO$_3$ doped with 5 percent of MgO. The free spectral range of the resonator was $\approx$3.42
GHz at wavelengths in the vicinity of 780 nm, the smallest full width at half maximum of a mode was ~50 MHz, and the thickness of the resonator in the area of mode localization was 30 µm. In the experiment, laser power of 9 mW was coupled into the resonator with an efficiency of 75 percent, and the laser was scanned over a frequency band 9 GHz wide at a nominal wavelength of ~780 nm. Resonance frequencies were measured as functions of time during several hours’ exposure to the laser light. The results of these measurements, plotted in the figure, show a pronounced collective frequency drift of the resonator modes. The size of the drift has been estimated to correspond to a change of 8.5 × 10⁻⁵ in the effective ordinary index of refraction of the resonator material.

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