Fabry-Pérot Cavity with Brewter Plate

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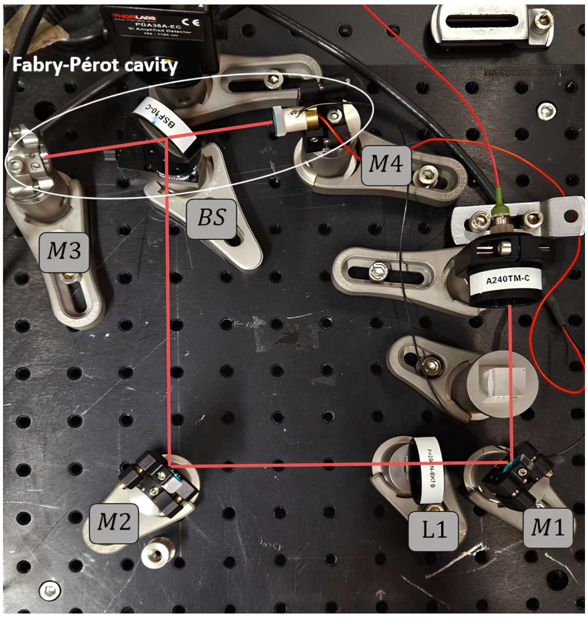
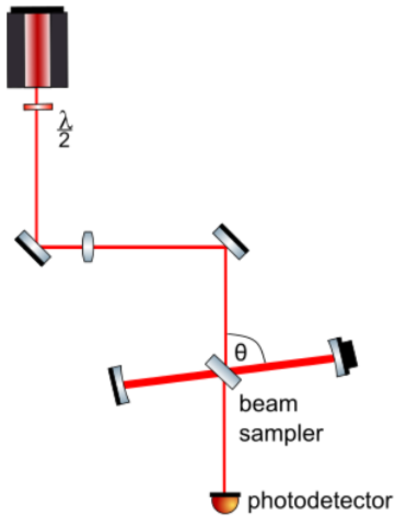
1 Theoretical Calculations

1. Fabry-Pérot Cavity

This alternative setup for a Fabry-Pérot cavity uses a beam sampler to couple light in and out of the cavity. The incident angle θ is close to the Brewster angle θ_B, so that the reflectivity R of the beam sampler is small and most of the light is transmitted. Therefore, p-polarized light is required.



(a) Experimental setup



(b) Scheme of the setup

The setup uses an incident angle of $\theta = 41°$, which corresponds to a reflectivity of $R = 1.08\%$. One of the mirrors is mounted on a piezoelectric element to modulate the cavity length and match it to the laser's wavelength.

Electric field amplitudes

With respect to the different beam rays and Figure 3, the field amplitudes follow:

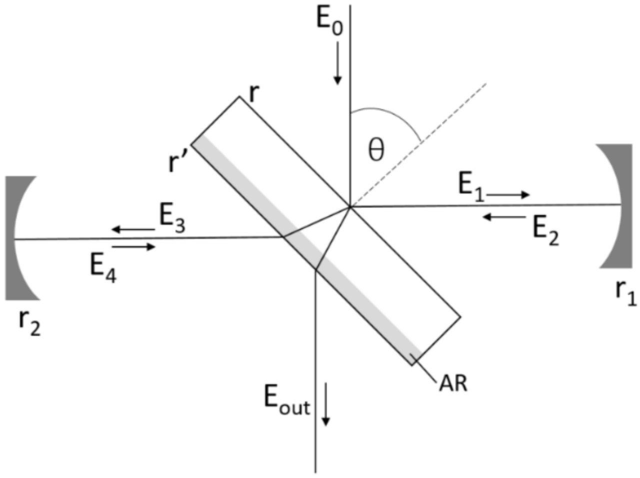


Fig. 2: Detailed scheme of the Brewster cavity. The beam sampler has an reflection coefficient r on the front side and an AR coated backside with a small reflection coefficient r'. The incident angle θ of the incoming light is close to the Brewster angle

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\begin{aligned}
E_1 &= r \cdot E_0 + tt' \cdot E_4 \\
E_2 &= r_1 \cdot E_1 \cdot e^{i\phi_1} \\
E_3 &= tt' \cdot E_2 \\
E_4 &= r_2 \cdot E_3 \cdot e^{i\phi_2} \\
E_{\text{out}} &= tt' \cdot E_0 - rt'^2 \cdot E_4
\end{aligned}
$$

After simplification, the output intensity normalized by the input intensity is given by:

$$\frac{I_{\text{out}}}{I_0} = \left|\frac{E_{\text{out}}}{E_0}\right|^2 = \left|tt' \cdot \frac{1 - t'^2 r_1^2 e^{i\Phi}}{1 - t^2 t'^2 r_1^2 e^{i\Phi}}\right|^2 \tag{1}$$

where $\Phi = \phi_1 + \phi_2$, and $r_2 = r_1$.

2. Impedance Matching

When comparing the gain $R \cdot |E_0|^2$ to the losses of the cavity:

$$(1 - R_1)|E_0|^2 + R \cdot |E_0|^2 + (1 - R_2)|E_0|^2 + (1 - T')|E_0|^2$$

it appears that full impedance matching cannot be realized, since R_1, R_2, and T' are strictly positive. Optimization of the matching requires high-quality components with minimized losses.

3. Finesse

To calculate the finesse F, Equation (1) is linearized around small phase deviations ($e^{i\phi} \approx 1 + i\phi$) and assuming $t \approx t' \approx 1$:

$$\left|\frac{E_{\text{out}}}{E_0}\right|^2 = \left|\frac{1 - t'^2 r_1^2 e^{i\Phi}}{1 - t^2 t'^2 r_1^2 e^{i\Phi}}\right|^2$$

At half maximum transmission, the phase satisfies:

$$\phi_{\text{FWHM}} = T_1 + R' + R \tag{2}$$

With the relation:

$$\phi = \frac{2\pi(\nu_l - \nu_{\text{cav}})}{\text{FSR}}$$

the finesse becomes:

$$F = \frac{\text{FSR}}{\Delta\nu} = \frac{2\pi}{2\phi_{\text{FWHM}}} = \frac{\pi}{T_1 + R + R'} \tag{3}$$

In our case : $R = 1\%$ et $R' = 0,5\%$ et $T_1 = 0,3\%$

4. Transmission of the Cavity Mirror

The transmission T_1 of the cavity mirror can be determined using:

$$|E_{t1}|^2 = t_1^2 \cdot |E_{\text{intracav}}|^2 \tag{4}$$

with

$$|E_{\text{intracav}}|^2 = |E_0^{\text{mm}}|^2 \cdot \frac{F}{\pi}$$

Assuming that all losses come from imperfect mode matching, the worst-case estimate is:

$$|E_0^{\text{mm}}|^2 = c \cdot |E_0|^2$$

where c is the measured fringe contrast. Thus, the transmission becomes:

$$T_1 = \frac{|E_{t1}|^2}{|E_0|^2} \cdot \frac{\pi}{c \cdot F} \tag{5}$$

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