Preparatory School to the Winter Collegue on Optics: Optical Frequency Combs

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## Thermal lens microscopy combined with intracavity absorption spectroscopy

The idea of the optical path length cavity amplifier is to increase the optical path of the probe beam by the use of two mirrors with reflectivities $R_1$ and $R_2$ as shown in figure 1. The relation between the incident $I_0$ and transmitted radiation of $n$ order $(n)$ $I_{Tn}$, is expressed by:

$$I_{Tn} = I_0(1-R_1)(1-R_2)(R_1 \cdot R_2)^n \quad (1)$$

Therefore, the total probe beam intensity reaching the detector $I_T$, when assuming, that there are no interference effects, is described by:

$$I_T = I_{T0} + I_{T1} + \cdots + I_{Tn} = I_0(1-R_1)(1-R_2)[1 + R_1 \cdot R_2 + (R_1 \cdot R_2)^2 + \cdots + R_1 \cdot {R_2}^n] \quad (2)$$

From equation 2 arises, that $I_T > 0$ only if the condition of $R_1 < 1$ and $R_2 < 1$ is fulfilled.

On the basis of equation 1 and calculating the sum of geometrical series in equation 2 assuming, that $|R_1 \cdot R_2| < 1$ and using the identity $1 + R_1R_2 + (R_1R_2)^2 + \ldots + (R_1R_2)^n = \frac{1}{1-R_1R_2}$, we got:

$$I_T = I_0 \frac{(1-R_1)(1-R_2)}{1-R_1 \cdot R_2} \quad (3)$$

If $R_1 = R_2 = R$ it is achieved:

$$I_T = I_0 \frac{(1-R)}{1+R} \quad (4)$$

It is seen from the last equation, that a threshold value of reflectivity exists, for which the light intensity reaching the detector is detectable.

It can be obtained from equation 1 the relative contribution of the $n$ order transmitted light beam $I_{Tn}$ in comparison to the cero order beam $I_{T0}$:

$$\frac{I_{Tn}}{I_{To}} = (R_1 \cdot R_2)^n \quad (5)$$

The number $N$ of times, that the $n$ order transmitted beam passed through the sample is:

$$N = 2n + 1 \quad (6)$$

On the basis of equation 5 it can be written:

$$N = 2\frac{\ln\left(\frac{I_{Tn}}{I_{T0}}\right)}{\ln\left(R_1 \cdot R_2\right)} + 1 \quad (7)$$

For an estimation of $N$ value, an assumption was done, that the transmitted beams of higher order still give contribution to the thermal lens signal, if their intensity was reduced to one order of magnitude compared to the zero order beam. Therefore, a condition in a form was received: $I_{Tn} = 10^{-1} I_{T0}$ , on the basis of which it was obtained:

$$N = -2\frac{\ln(10)}{\ln\left(R_1 \cdot R_2\right)} + 1 \quad (8)$$

However $N$ can be obtained experimentally, due to that it is necessary to choose $2\ln\left(\frac{I_{Tn}}{I_{T0}}\right) = P$ as a fitting parameter. Thus:

$$N = \frac{P}{\ln\left(R_1 \cdot R_2\right)} + 1 \quad (9)$$

Using this equation it is possible to determine $P$ value for the specific configuration of the experimental setup with fixed value of $R_1$ and $R_2$. Having $P$ determined, it is possible to calculate the relative contribution of the $n$ order transmitted beam $I_{Tn}$ compared to the zero order transmitted beam $I_{T0}$. Furthermore, more precise estimation of $N$ value can be done for different mirror reflectivities.

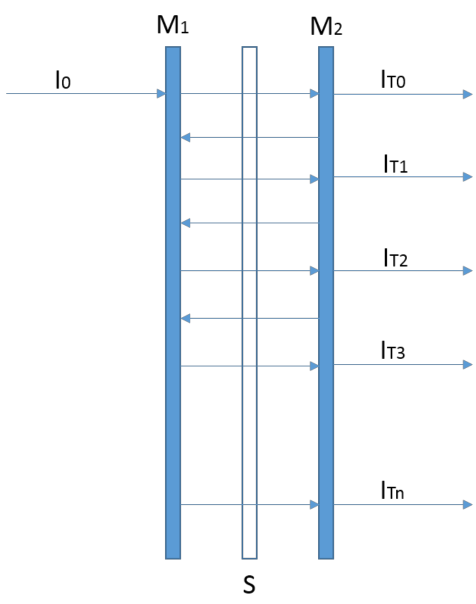


Fig.1. Experimental configuration of the optical path length cavity amplifier