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THE LOSSES MEASUREMENT FOR OPTICAL CAVITY WITH FABRY-PEROT ETALON

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Abstract

An intracavity glass plate with parallel planes changes dramatically light decay in optical cavity. This effect should be taken into account for measuring losses of optical cavity.

As it was shown in [1] glass plate with parallel planes placed inside optical cavity dramatically reduces the free electron laser (FEL) linewidth. However, this plate also increases losses of light captured in optical cavity due to adsorption and imperfections of the glass plate. This increase of losses is important to the FELs with gain few percents per pass or less. In case of the optical cavity with the intracavity plate method of losses measurement based on measuring time decay constant of captured light should be modified.

A simple model is that the losses of optical cavity are a sum of the losses on mirrors, the absorption of the glass plate, and losses due to Fabry-Perot etalon and are defined by formula:

$$p = p_o + 4R(1+\cos kD) , \qquad (1)$$

where p_o - minimal losses, $R=((n-1)/(n+1))^2$, n - refractionindex, $D=2nd$, d - the plate thickness, k - the wavenumber. This assumption is valid due to the fact that angle between normal of the plate and the cavity axis may be much greater than accuracy of adjusting of the optical cavity mirrors [1] and we may assume that light reflected by the plate is lost on the walls of a vacuum chamber.

Therefore the decreasing intensity of light captured in the optical cavity may be evaluated by an integral

$$I = \int \frac{E(k)\ e^{-p(k)t/T}}{p(k)} dk \ , \qquad (2)$$

where $E(k)$ - spectral intensity of spontaneous radiation from undulator, T - period of roundtrip of the light in the optical cavity. The dependence of p on k is strong and we are interested only in p_o value, therefore we may use a monochromator with high resolution $\delta k < D^{-1}$. But this method leads to small intensity of light. So, we used monochromator with the resolution $\delta k \gg D^{-1}$. In this conditions neglecting the dependence of E and p_o on k we have

$$I = \frac{P\Delta k}{2\pi} \int_0^{2\pi} \frac{e^{-(p_o+4R(1+cos(kD))t/T}}{p_o+4R(1+cos(kD))} d(kD) \ . \qquad (3)$$

For $t > T/R$ we may simplify (3) by changing $\cos(\pi+\varphi)$ on $\phi^2/2-1$

$$I = \frac{P\Delta k}{2\pi} \int_{-\pi}^{\pi} \frac{e^{-(p_o+4R\varphi^2)t/T}}{p_o+4R\varphi^2} d\varphi \qquad (4)$$

and taking the integral in the infinite limits:

$$I = \frac{P\Delta k}{2\sqrt{p_o R}} erfc(\sqrt{p_o t/T}), \quad (5)$$

$$erfc(x)= \frac{2}{\sqrt{\pi}} \int_x^\infty exp(-t^2)dt.$$

Note that the shape of this curve does not depend on R.

This model was also verified by numerical integration for the conditional values p_o=0.04 and n=1.5. Results of modeling are shown in the Figure. Curve "cosine" corresponds to the losses modulated by cosine law, curve "parabola" corresponds to a parabolic approximation of cosine function. From the Figure it is seen that both curves are practically the same and sufficiently differ from exponent corresponded to optical cavity having losses p_o per roundtrip shown as curve "exponent". This method allowed to measure the real losses of the optical cavity with installed Fabry-Perot etalon.

REFERENCE

[1] Litvinenko V.N. *et al.* The Results of Lasing Linewidth Narrowing on VEPP-3 Storage Ring Optical Klystron. IEEE Journal of Quantum Electronics, v.27(1991), pp.2560-2565.

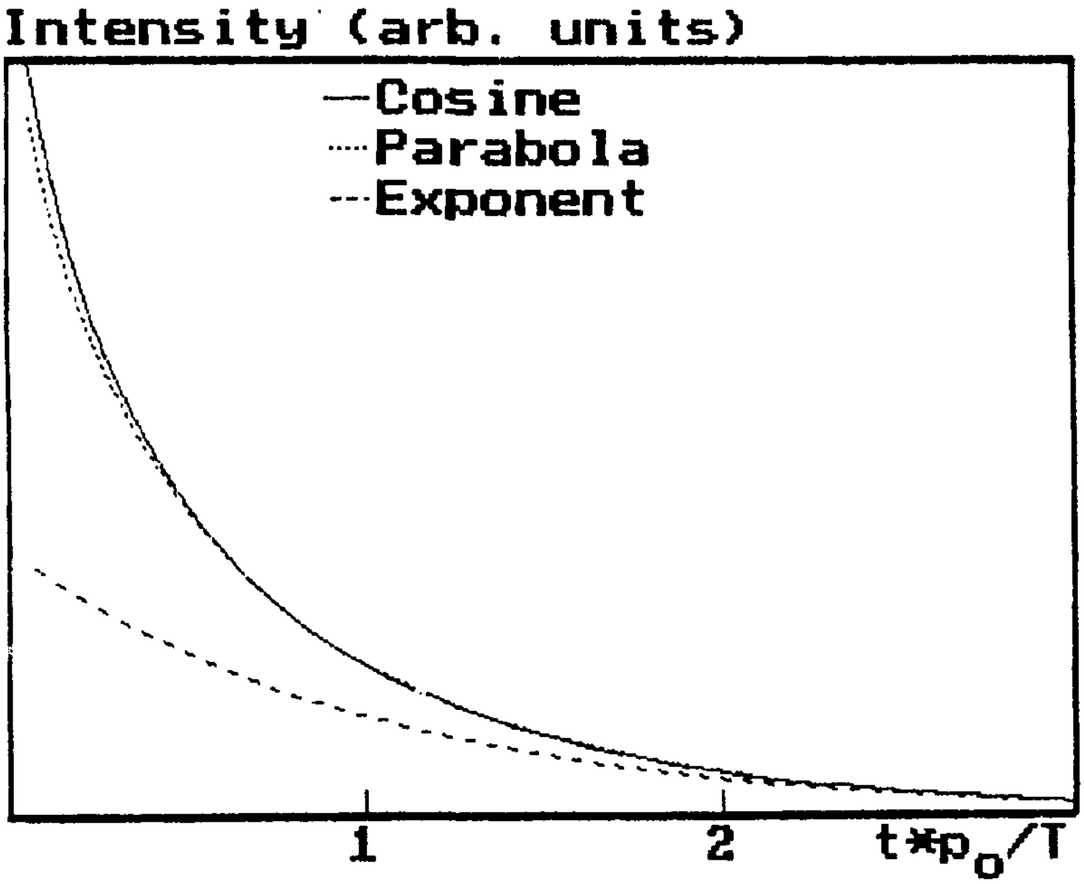

Fig. Decay curves for various integrals

$$\text{Cosine:}\quad I = \frac{P\Delta k}{2\pi}\int_0^{2\pi} \frac{e^{-(p_o+2R(1+\cos(kD))t/T}}{p_o+2R(1+\cos(kD))}\, d(kD)$$

$$\text{Parabola:}\quad I = \frac{P\Delta k}{2\pi}\int_{-\pi}^{\pi} \frac{e^{-(p_o+R\varphi^2)t/T}}{p+R\varphi^2}\, d\varphi$$

$$\text{Exponent:}\quad I = exp(-p_o t/T)$$

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