# PREDICTED PARAMETERS OF THE SECOND STAGE OF HIGH POWER NOVOSIBIRSK FEL

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*Abstract*

The first stage of Novosibirsk high power terahertz FEL was successfully put into operation in 2003 [1]. The measured parameters of the FEL turned out to be in a good agreement with calculations [2]. The second and the third stages of the FEL are under construction now. The beam energy at the second stage will be about 20 MeV and the wavelength range is 40-80 μm. In this paper we present the design parameters for the second stage FEL. The simulations were carried out with the help of 1-D code, based on macroparticles. This code was previously used for the first stage simulations [2].

## INTRODUCTION

The second stage for Novosibirsk FEL consists of the 4-orbit electron accelerator-recuperator, or energy recovery linac (ERL). Our calculations refer to the second orbit of the accelerator, where the bypass with FEL is inatalled. The scheme of the second orbit bypass with an undulator in it is presented in Fig.1. The path delay is 65 cm. When the bypass magnets are switched on, the beam goes through the undulator. Inside the undulator the electron beam interacts with radiation, and returns to the main orbit after that. As the used beam is delayed, it is decelerated in the ERL accelerating structure and therefore goes not to the third, bit to the first orbit for further deceleration after that.

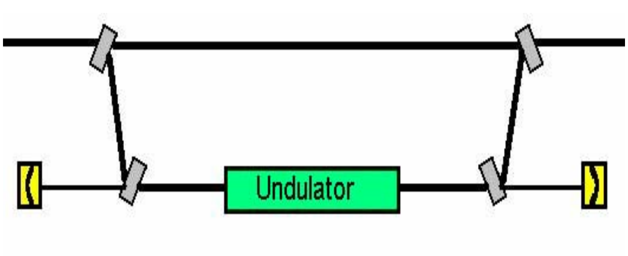


Figure 1: The second stage of the FEL.

## PARAMETERS

Each FEL is described by several parameters. Here are presented for the second stage of Novosibirsk FEL:

| | |
|---|---|
| Undulator Length | 4 m |
| Undulator Period | 12 cm |
| Optical resonator length | 20 m |

Electron beam parameters are listed below:

| | |
|---|---|
| Particle Energy | 20 MeV |
| RMS Energy Spread | 0.0019 |
| RMS Longitudinal Spread | 2.585 ps |
| Charge per Bunch | 1.5 nC |

As the effective Gaussian mode area in the resonator (0.8 $cm^2$) is much bigger than the effective size of the electron beam (0.1 $cm^2$), the 1-D approximation is valid [2]. The initial beam energy-time distribution (Fig. 2) was obtained from the numerical simulation of particle longitudinal motion in ERL.

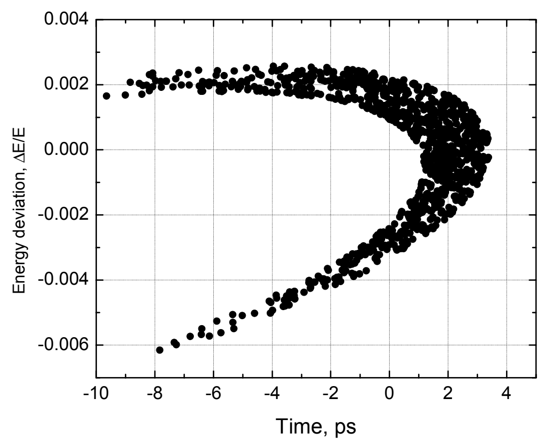


Figure 2: Longitudinal phase space distribution of particles.

## RESULTS

The calculation algorithm is described in [2]. It uses several longitudinal modes for the field calculation, and macroparticles for simulation of the longitudinal density of electrons. Below we present results of these calculations for the second stage of Novosibirsk FEL.

The obtained power dependence on the detuning between the optical resonator round-trip frequency and electron beam repetition frequency is shown in Fig. 3. The maximum intracavity power is 47 kW.

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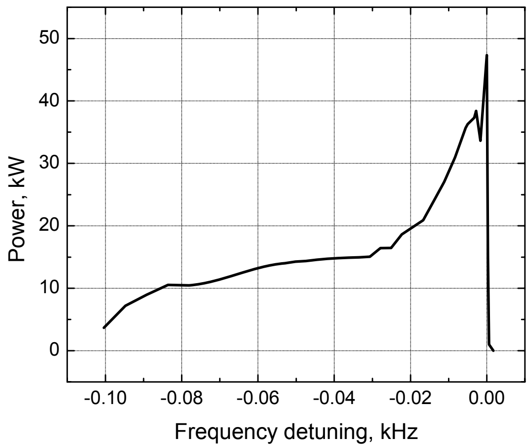


Figure 3: Frequency detuning curve.

Some examples of the power saturation level depedence on the pass number for different detunings are shown in the Fig. 4. One can see that there is no stable saturation level at some detunings. That may be caused by complexity and nonlinearity of the problem.

In Fig. 5 and 6 one can see the characteristics spectrums (for detunings 85 and 15 Hz correspondingly). The spectrum (Fig. 6) consists of few peaks, which corresponds to the sideband (modulation) instability (see Fig. 8). The distance between peaks in Fig. 8 is equal to the slippage between beam and the wave packet on the undulator exit.

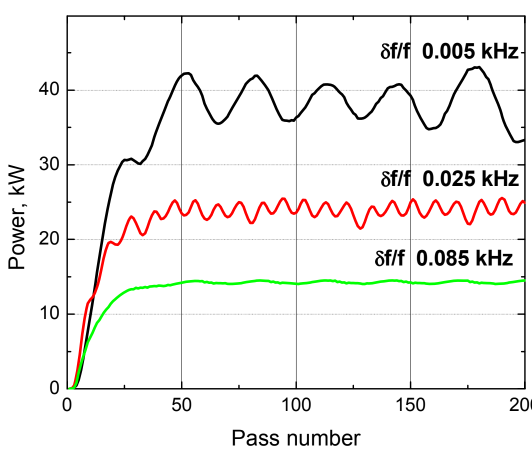


Figure 4: Dependence of intracavity power on the pass number.

One of important parameters is the FEL amplification in linear regime. To find it the intracavity power dependence on the amplitude decay coefficient (the amplitude depression when wave packet reflects from optical resonator mirrors) has been obtained. The calculations have been performed for two detunings (0 Hz and 85 Hz). The results are shown in figure 9. One can see that oscillation stops when decay coefficient exceeds 0.5. That is the evidence that the amplification of wave packet passing through the FEL in the linear regime is near 2.

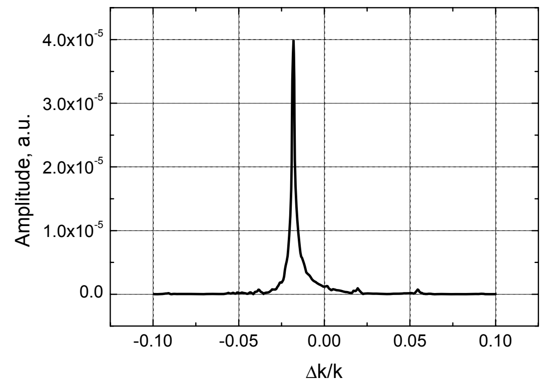


Figure 5: Spectrum for 85 Hz detuning.

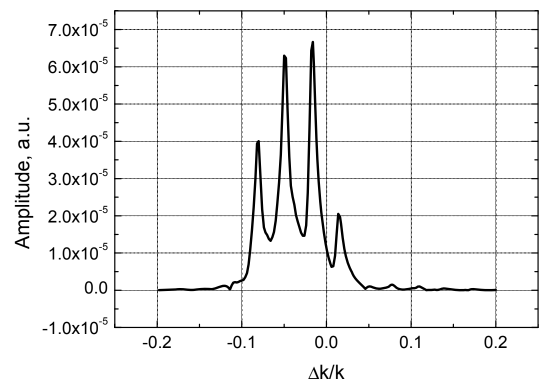


Figure 6: Spectrum for 15 Hz detuning.

The optimum size for hole for the power output has been also calculated. We assume that power losses by the mirror reflectivity are approximately 0.10. The coupling hole adds doubled output power to these losses. In Fig. 7 one can see the output power dependence on the total losses coefficient .

## CONCLUSION

This paper describes calculations of Novosibirsk FEL second stage parameters. At the wave length near 60 microns. the calculated output is more than 1 kW. Optimized coupling (loss) of the optical resonator was found.

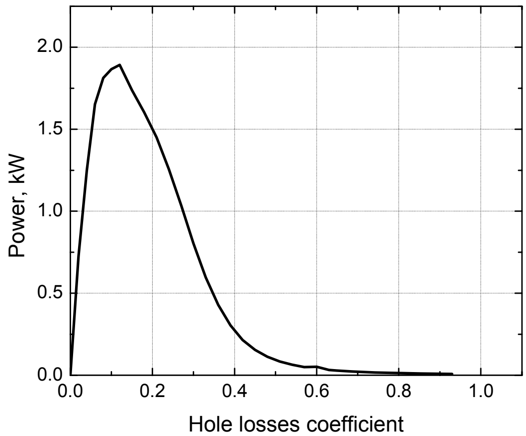


Figure 7: The output power dependence on losses in optical resonator hole.

The new approach based on the distribution function calculation is being developed now. The new simulation code is written and tested for the small signal case.

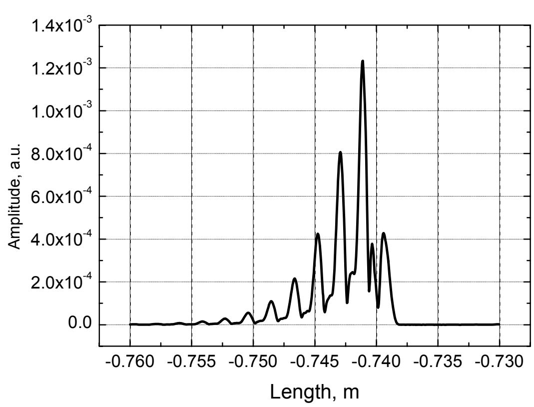


Figure 8: Wave packet for 15 Hz detuning.

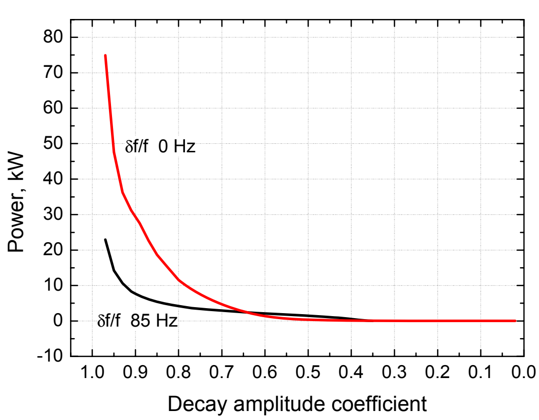


Figure 9: Power dependence on decay amplitude coefficient.

## REFERENCES

[1] Antokhin E.A. et al. NIM A528 (2004) p.15-18.

[2] Kuzmin A.V., Shevchenko O.A., Vinokurov N.A. NIM A543 (2005) p.114-117.