

# Study of the generation intensity in the backward wave oscillator with a "grid" diffraction grating as a function of the grating length

V.G. Baryshevsky, N.A.Belous, V.A.Evdokimov,  
A.A.Gurinovich, A.S.Lobko, P.V.Molchanov, P.F.Sofronov,  
V.I.Stolyarsky.

*Research Institute for Nuclear Problems, Belarussian State University,  
11 Bobruyskaya Str. , Minsk 220050, Belarus*

---

## Abstract

Experimental studies of the backward wave oscillator with a "grid" diffraction grating that is formed by a periodic set of metallic threads inside a rectangular waveguide are proceeded with study of the generation intensity as a function of the grating length.

*Key words:* Volume Free Electron Laser (VFEL), Volume Distributed Feedback (VDFB), diffraction grating, backward wave oscillator

*PACS:* 41.60.C, 41.75.F, H, 42.79.D

---

Generation of radiation in millimeter and far-infrared range with nonrelativistic and low-relativistic electron beams gives rise difficulties. Gyrotrons and cyclotron resonance facilities are used as sources in millimeter and sub-millimeter range, but for their operation magnetic field about several tens of kiloGauss ( $\omega \sim \frac{eH}{mc}\gamma$ ) is necessary. Slow-wave devices (TWT, BWT, orotrons) in this range require application of dense and thin ( $< 0.1$  mm) electron beams, because only electrons passing near the slowing structure at the distance  $\leq \lambda\beta\gamma/(4\pi)$  can interact with electromagnetic wave effectively. It is difficult to guide thin beams near slowing structure with desired accuracy. And electrical endurance of resonator limits radiation power and density of acceptable electron beam. Conventional waveguide systems are essentially restricted by the requirement for transverse dimensions of resonator, which should not significantly exceed radiation wavelength. Otherwise, generation efficiency decreases abruptly due to excitation of plenty of modes. The most of the above problems

can be overpassed in VFEL [1,2,3,4,5]. In VFEL the greater part of electron beam interacts with the electromagnetic wave due to volume distributed interaction. Transverse dimensions of VFEL resonator could significantly exceed radiation wavelength  $D \gg \lambda$ . In addition, electron beam and radiation power are distributed over the whole volume that is beneficial for electrical endurance of the system.

The electrodynamic properties of volume diffraction structures composed from strained dielectric threads was experimentally studied in [6]. The electrodynamic properties of a "grid" volume resonator formed by a periodic structure built from the metallic threads inside a rectangular waveguide was considered in [8]. First observation of lasing of the backward wave oscillator with a "grid" diffraction grating and the volume FEL with a "grid" volume resonator that is formed by the periodic set of metallic threads inside a rectangular waveguide was described in [9].

In the present paper dependence of the generation intensity as a function of the grating length is studied for the backward wave oscillation regime.

The "grid" diffraction grating is built from tungsten threads with diameter 0.1 mm strained inside the rectangular waveguide with the cross-section 35 mm x 35 mm and length 300 mm (see Fig.1). The distance between the threads along the axis  $OZ$  is  $d_z = 12.5$  mm. A circular electron beam with the diameter 32 mm, the energy  $\sim 200$  keV and current  $\sim 2$  kA passes through the above structure. Period of grating is chosen to provide radiation frequency  $\sim 8.4$  GHz. The "grid" structure is made of separate frames each containing the layer of 1, 3 or 5 parallel threads with the distance between the next threads  $d_y = 6$  mm). Joining frames provides to get the "grid" structure with layers distant  $d_z$  each from other.

The purpose of the experiment is to study dependence of the generated radiation intensity on the "grid" grating length (i.e. on the number of frames). Two types of experiments are reported: with one thread in the frame and with 5 threads in the frame.

In the case of one thread in the frame the maximal radiation power is about 1.5 kWatt. The radiation power is measured for 4, 8, 10 and 24 frames each containing one thread equidistant from waveguide top and bottom walls. The result of these measurements is presented in Fig.2, where the radiation power is normalized to the maximal detected power.

In the case of five threads in the frame the maximal radiation power is about 8 kWatt. The radiation power is measured for 4, 6, 10, 12, 14 and 22 frames each containing five threads distant  $d_y = 6$  mm each from other (see Fig.1). The result of these measurements is presented in Fig.3, where the radiation power is also normalized to the maximal detected power.

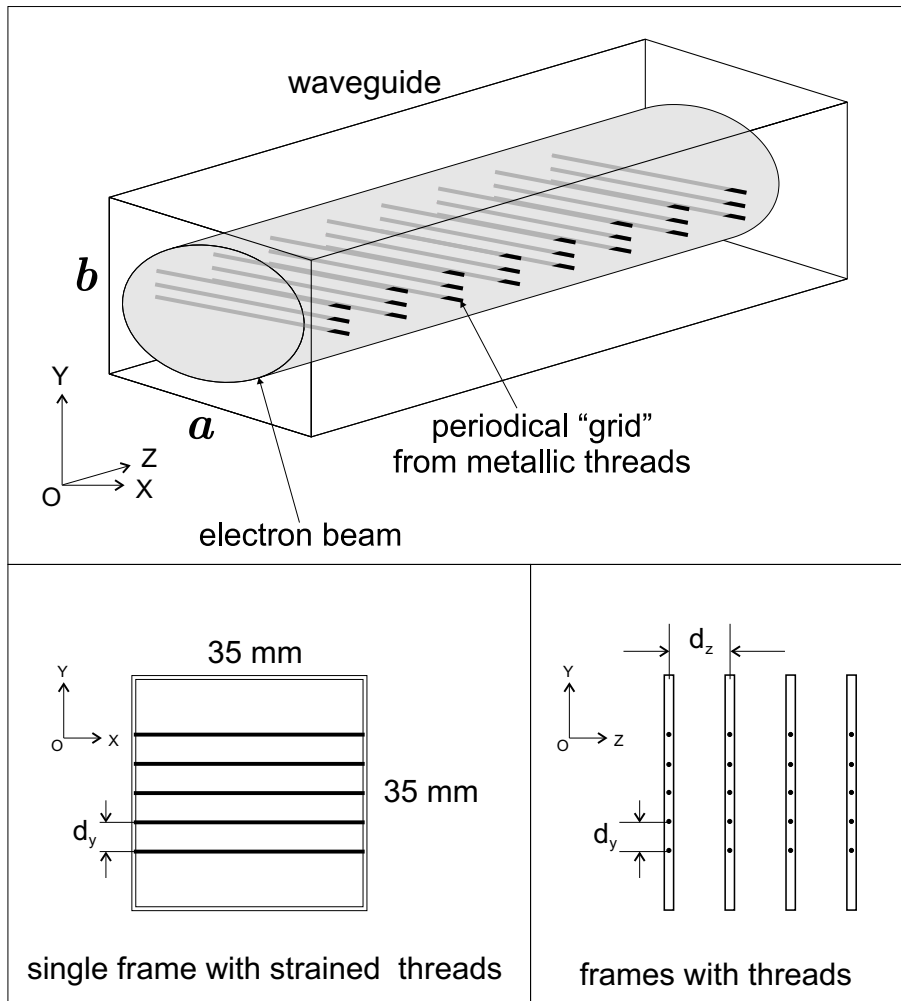


Fig. 1. The "grid" diffraction grating placed inside the waveguide

## References

- [1] V.G. Baryshevsky, I.D. Feranchuk, Phys.Lett. **102A**, 141 (1984).
- [2] V.G. Baryshevsky, LANL e-print archive physics/9806039.
- [3] V.G. Baryshevsky, K.G. Batrakov, A.A. Gurinovich et al., NIM **483A** (2002) 21-23.
- [4] V.G. Baryshevsky, K.G. Batrakov, A.A. Gurinovich et al., NIM **507A** (2003) 137-140.
- [5] Eurasian Patent no. 004665.
- [6] V.G. Baryshevsky, K.G. Batrakov, I.Ya. Dubovskaya, V.A. Karpovich, V.M. Rodionova, NIM **393A**, 71 (1997).
- [7] V.V. Nikolsky, Electrodynamics and propagation of radio-wave (Nauka, 1978)
- [8] V.G. Baryshevsky, A.A. Gurinovich LANL e-print archive: physics/0409107

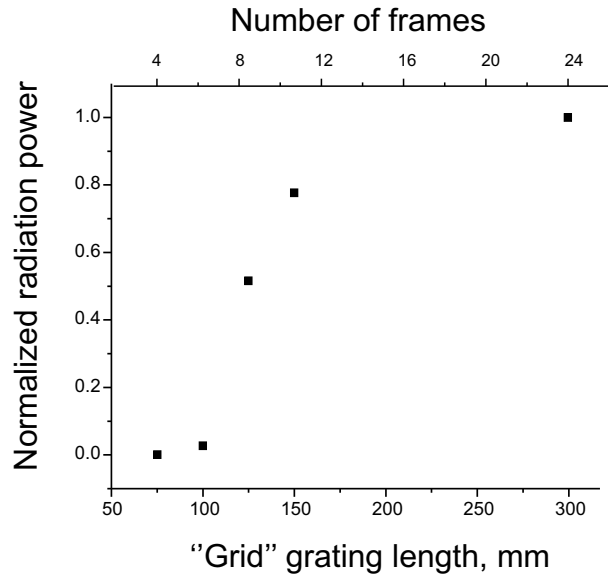


Fig. 2. Dependence of the generation intensity on the "grid" grating length for 1 thread in the frame

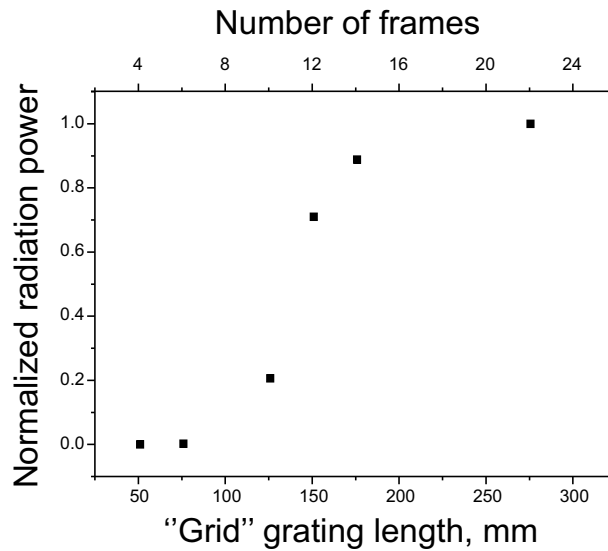


Fig. 3. Dependence of the generation intensity on the "grid" grating length for 5 threads in the frame

[9] V.G. Baryshevsky, K.G. Batrakov, N.A. Belous, A.A. Gurinovich, A.S. Lobko, P.V. Molchanov, P.F. Sofronov, V.I. Stolyarsky, LANL e-print archive: physics/0409125.