

# First observation of generation in the backward wave oscillator with a "grid" diffraction grating and lasing of the volume FEL with a "grid" volume resonator

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

*Research Institute of Nuclear Problem, Belarussian State University,  
11 Bobruyskaya Str. , Minsk 220050, Belarus*

---

## Abstract

First observation of generation in the backward wave oscillator with a "grid" diffraction grating and lasing of the volume FEL with a "grid" volume resonator that is formed by a periodic set of metallic threads inside a rectangular waveguide is considered.

*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]. In [8] it was shown that nonrelativistic and low-relativistic electron beams passing through such structures can generate in wide frequency range up to terahertz. 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 [9].

In the present paper 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 a periodic set of metallic threads inside a rectangular waveguide (see Fig.1) is considered. According to the analysis [9] a "grid" volume resonator was built from tungsten threads with diameter 0.1 mm strained inside the rectangular resonator with transverse dimensions 45 mm x 50 mm and length 300 mm (see Fig.3). Distance between threads was 12.5 mm. Annular electron beam with the energy 200 keV and electron beam current 2kA passed through the above resonator. As it was mentioned above only electrons passing near the slowing structure at the distance  $\delta \leq \lambda\beta\gamma/(4\pi)$  can interact with electromagnetic wave effectively. In our case annular electron beam with the outer radius 16 mm and the ring width 4 mm passes through a "grid" diffraction grating. As a result, the part of the electron beam moving close to the grating inside the interval  $2\delta$  interacts with the grating effectively Fig.3. The purpose of experiment was to prove possibility of lasing in such a resonator and to examine "grid" volume resonator durability.

Two different experiments were carried out (Fig.1, Fig.3): the experiment providing to observe generation in backward wave oscillator with a "grid" diffraction grating and lasing of the volume FEL with a "grid" volume resonator.

The first experiment was done to test the system as a backward wave oscillator. Radiation pulse with power about 1 kWatt was registered.

Then additional diffraction grating (Fig.3) was placed inside the resonator to provide volume distributed feedback in the system. Lasing of volume free electron laser with "grid" volume resonator was studied. Radiation pulse with frequency 10 GHz and power about 10 kWatt was registered.

Thus, durability of "grid" volume resonator and possibility of lasing in such a resonator was proved.

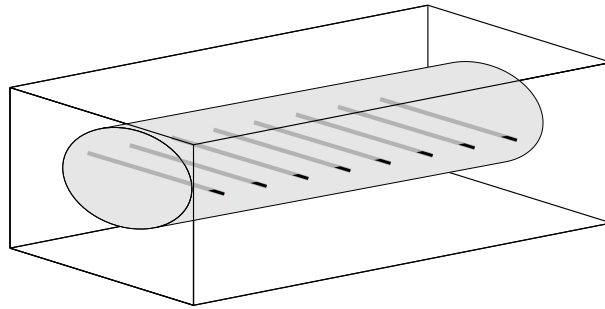


Fig. 1. A backward wave oscillator with the "grid" diffraction grating

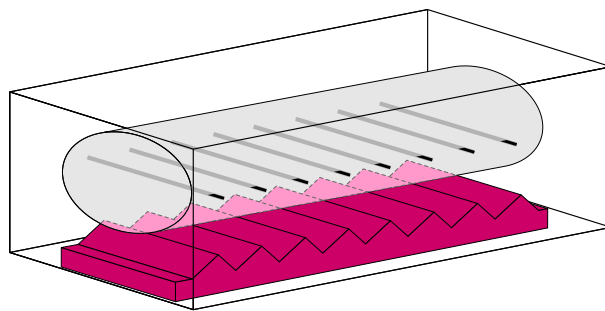


Fig. 2. "Grid" volume resonator

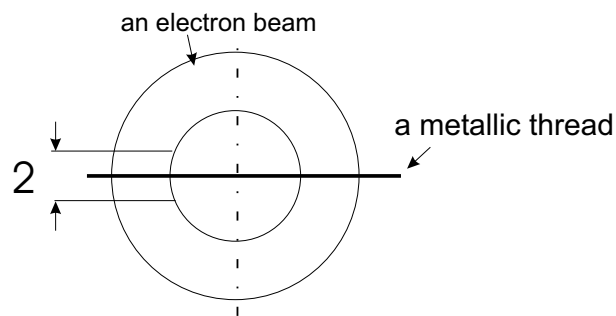


Fig. 3. Annular electron beam interacts with "grid" grating

The experiments with several parallel "grid" gratings are in progress now.

## 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.Batnikov, I.Ya.Dubovskaya, V.A.Karpovich, V.M.Rodionova, NIM **393A**, 71 (1997).
- [7] Nikolsky V.V., Electrodynamics and propagation of radio-wave (Nauka, 1978)
- [8] V.G.Baryshevsky, K.G.Batnikov, V.I.Stolyarsky, NIM **507A**, 93-96 (2003).
- [9] V.G.Baryshevsky, A.A. Gurinovich LANL e-print archive: physics/0409107