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# THE MAGNETIC SYSTEM OF AN OPTICAL KLYSTRON USING SmCo PERMANENT MAGNETS

G.A. KORNYUKHIN, G.N. KULIPANOV, V.N. LITVINENKO,
N.A. VINOKUROV and P.D. VOBLYI
*Institute of Nuclear Physics, 630090, Novosibirsk, USSR*

The particular problems in the design of an optical klystron (OK) magnetic system using samarium–cobalt permanent magnets are considered here. Two variants of such a system installed and commissioned at the VEPP-3 storage ring are briefly described.

A modification of a free electron laser – an optical klystron (OK) – was proposed at the Institute of Nuclear Physics in 1977 [1]. Its magnetic system consists of two plane magnetic snakes (undulators) with the bunching section between them. The latter significantly increase the gain in comparison with a conventional free electron laser of the same length. The operation principles of the OK were described in our previous papers (see, for example, refs. 2, 3). In the present paper we consider only the structure of the OK magnetic system.

For the OK installed on the VEPP-3 storage ring, taking into account external constraints, the following parameters were defined:

| | | |
|---|---|---|
| 1. | Electron energy | $E = 360$ MeV |
| 2. | Relative energy spread | $\sigma_E/E = 2\times10^{-4}$ |
| 3. | Transverse sizes of the electron at the site of the OK | $\sigma_x = 0.2$ mm<br>$\sigma_z = 0.1$ mm |
| 4. | Corresponding angular spreads | $\sqrt{\langle\theta_x^2\rangle} = 5\times10^{-5}$<br>$\sqrt{\langle\theta_z^2\rangle} = 4\times10^{-5}$ |
| 5. | Full length of free space for the installation of the OK | 1.1 m |
| 6. | Minimum vertical aperture of the magnetic system | 11 mm |
| 7. | Operating wavelength | 0.63 $\mu$m |

In 1979 the first and in 1981 the second OK magnetic system were installed in the straight section of VEPP-3. Their main parameters are shown in table 1.

In both the first and the second magnetic system rectangular pieces of SmCo magnetic material 4 cm × 4 cm × 1 cm with the magnetization vector parallel to the small edges were used. The magnetic material has a magnetic energy $\frac{1}{2}(BH)_{\max} = 8\times10^6 \mathrm{G}\cdot\mathrm{Oe}$, a remanent field $B_r = 8.3$ kG, coercive strength $H_c = 7.4$ kOe, the spread of the magnetization magnitude from one piece to another $\pm7\%$.

The layout of the snake period in OK-1 is shown in fig. 1. Magnetic pieces (1) are assembled on the iron foundation (2), and the magnetization is vertical. The spread of magnetization is compensated by thin iron plates (3) whose thickness was chosen during the magnetic measurements. These plates also provide homogeneity of field inside the magnetic material and so make it possible to use its magnetic energy optimally. The structure of the buncher is the same but the thickness of the magnetic material is twice as great and the length of period is 34 cm.

The results of the experimental investigation of the OK-1 spontaneous radiation spectrum [2] confirmed our theoretical considerations. In the spring of 1980 we measured the gain in OK-1 [3, 4]. These results were also in good agreement with theory.

To increase the gain, at the beginning of 1981 the new, more advanced, magnetic system OK-2 (figs. 2 and 3) produced [3]. It has higher number of periods in snakes and higher longitudinal dispersion (see table 1). In the snakes of OK-2 the magnetization vector is directed horizontally and the iron poles (11 mm thickness) concentrate the magnetic flow. Each pole is supported by the vertical adjusting screw and one can easily vary the gap and hence the field in each half-period of the snake. To localize this field variation there are thin (1.5 mm) iron liners between half-periods of the

Table 1
Parameters of the two OK magnetic systems at VEPP-3

| Snakes | OK-1 | OK-2 |
|---|---|---|
| Period [cm] | 10 | 6.5 |
| Number of periods | 2×3 | 2×4.5 |
| Maximum magnetic field [kG] | 3 | 7 |
| Pole width [cm] | 8 | 2,7 |
| Buncher length [cm] | 34 | 34 |
| Maximum magnetic field kG | 5.7 | 11 |
| Pole width [cm] | 8 | 4 |

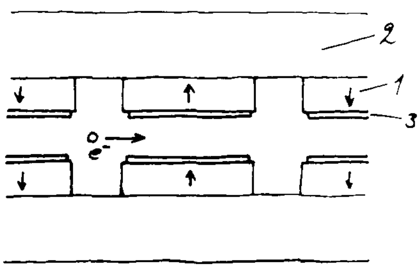


Fig. 1. The layout of one period of the snake in the OK-1. 1 – permanent magnets, 2 – iron foundation, 3 – iron plates (thin pole pieces).

snake. The liners are connected to the iron foundation and therefore keep the magnetic potential at the borders of each half-period equal zero. To decrease parasitic magnetic flows the height and the width of poles are less than the corresponding sizes of the pieces of magnetic material. Note that in the snakes with permanent magnets with such type of structure one can produce fields as high as 20 kG.

In the bunching section we use concentration of the magnetic flow not in the longitudinal but in the transverse directions. To provide a small variation of longitudinal dispersion 6 small coils (one on each pole) connected in series are used. There are also two bigger auxilary coils around the whole bunching section which

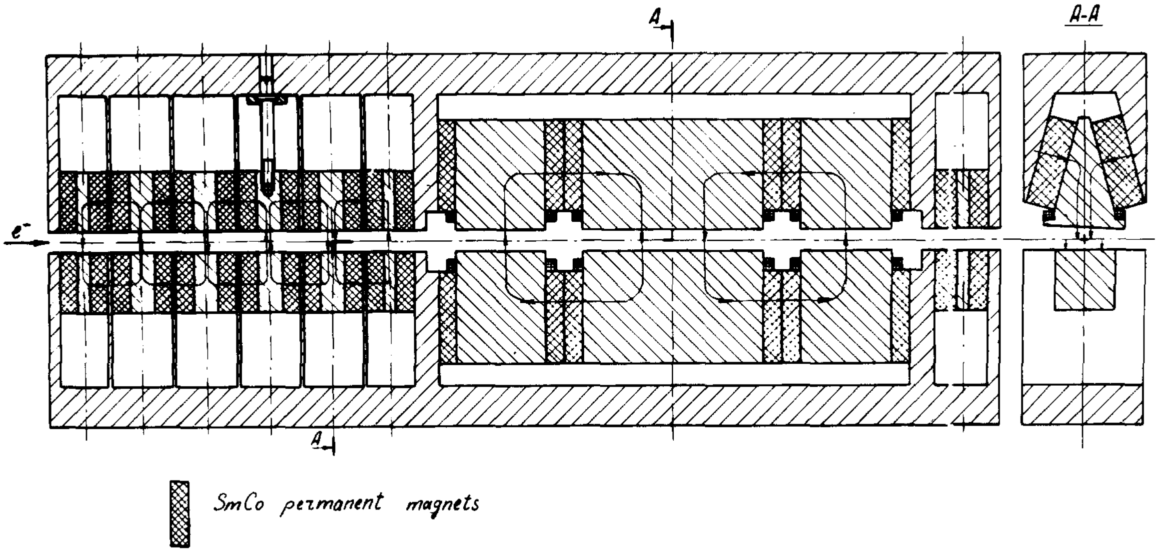


Fig. 2. The layout of the OK-2.

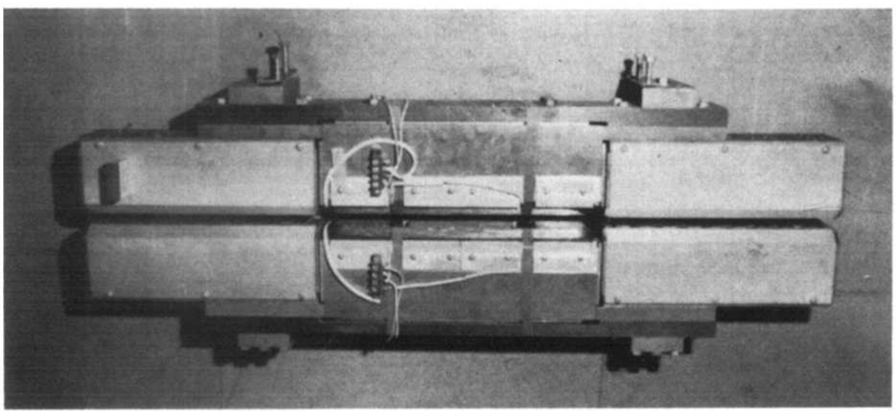

Fig. 3. The assembled magnetic system OK-2.

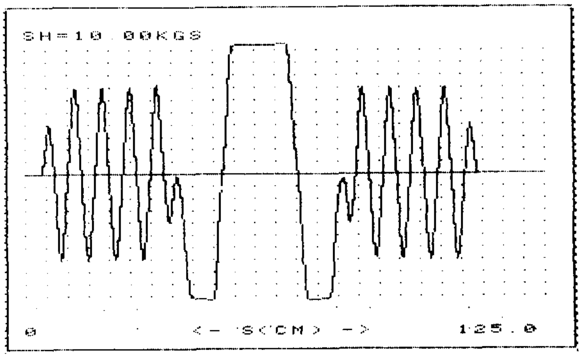


Fig. 4. The vertical magnetic field in the OK-2 versus longitudinal coordinate.

make the residual vertical field integral $\int H_z dS$ equal to zero. Changing the pole pieces one can easily provide a transverse gradient of field $\partial H_z/\partial x$ for the gain expansion [3,5]. The gain of OK-2 is expected to be higher than in the case of OK-1 by more than a factor 5.

The measured longitudinal dependence of the vertical magnetic field in OK-2 is shown in fig. 4. The values of the field are in good agreement with calculations which were based on the approximate analysis of the permeances. Note that the field inside almost all permanent magnets of the OK-2 is near the "optimal" value 4 kG. Thus the use of iron in the permanent magnet snakes (i) eliminates the influence of the spread of magnetization on the field, (ii) makes it possible to use optimally the magnetic energy of the material, (iii) facilitates the field forming.

## References

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