High Precision Particle Beam Choppers

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Summary

The special requirements of fast rotating particle beam choppers comply best with magnetic bearings. Three types of magnetic bearings for rotor weights between 1 kg and 12 kg are described, which are used in chopper systems. The most important advantages of this bearings are a very low power consumption, a high phase stability and the suitability for high vacuum.

Chopper systems are used in many laboratories and in industry to cut particle beams into packages of known size or energy. This technique is used in the fields of fundamental research, material research and of surface analysis of semiconductors for example.

Usually the particle beams are cut by fast rotating discs, which allow the beams to pass through a couple of windows. The speed of rotation may be in the order of 1 kHz.

Chopper systems are often part of much bigger and very expensive devices. In some cases they may be activated by neutron beams. So it is obvious, that the chopper bearings shall be designed for high life time and high reliability and that they shall show no bearing wear.

In many fields of application it is necessary to have chopper rotors running under vacuum. In these cases it is better to use bearings without lubrication oil.

The above mentioned requirements on chopper bearings disqualify the use of ball bearings. On the other hand active magnetic bearings fit very well the requirements mentioned above.

But in many cases there are additional specifications which

favour special types of magnetic bearings among many others. For example there is often the claim for an extremely high accuracy of phase control, if several choppers are used together in a chopper cascade. This can only be fullfilled, if the required motor power is very small compared with the energy of rotation. In this case it is of advantage to use the zero power magnetic bearings, which have been developed by the Kernforschungsanlage in Jülich and which have been manufactured under license by our company for serveral years.
The very small power loss of this bearing type is possible, because the rotor weight is fully compensated by permanent magnets. Only small electric power is necessary to stabilize the rotor position in the center of the bearing.

Eddy current losses in the rotor are small, because the field of the permanent magnets and of some electromagnets has only small deviations to an axially symmetrical shape. That is why the rotors of our chopper systems have a homogeneous not laminated structure which is suitable for the use in high vacuum.
Another condition for the application of choppers in high vacuum is the great radial gap between rotor and stator magnets, which is necessary to separate rotor and stator by a vacuum tube. The stator packet can easily be removed from the vacuum tube to clean the vacuum surfaces by heat treatment.

The figures 1 to 7 show the design of the two magnetic bearings type I and II, which have been manufactured by us for several aplications. The bearing type III, which has been developed also by the KFA (fig. 8), is now built for the Hahn Meitner Institute.

On fig. 1 you can see a cross section through the chopper type I, which has two magnetic bearings symmetrically arranged.

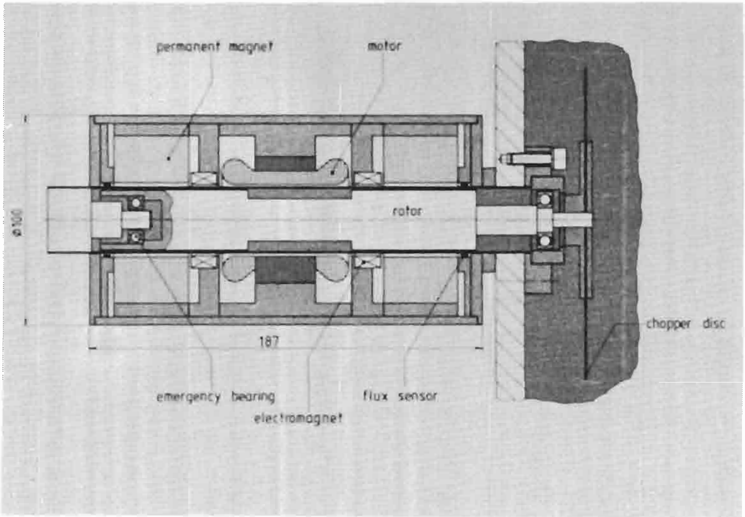

Fig. 1. Cross section of the chopper type I

Fig. 2 shows a total view of this chopper but without the chopper disc. Different kinds of discs may be mounted on the left side to adapt the chopper to the special requirements of molekular beams or neutron beams for example.

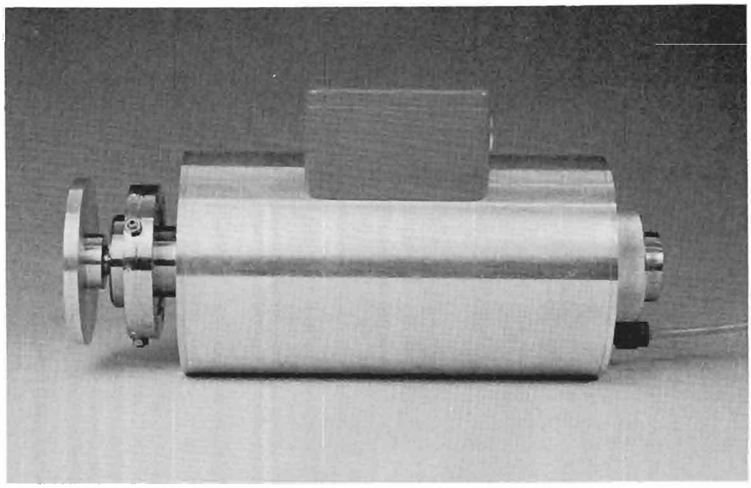

Fig. 2. Total view of the chopper type I

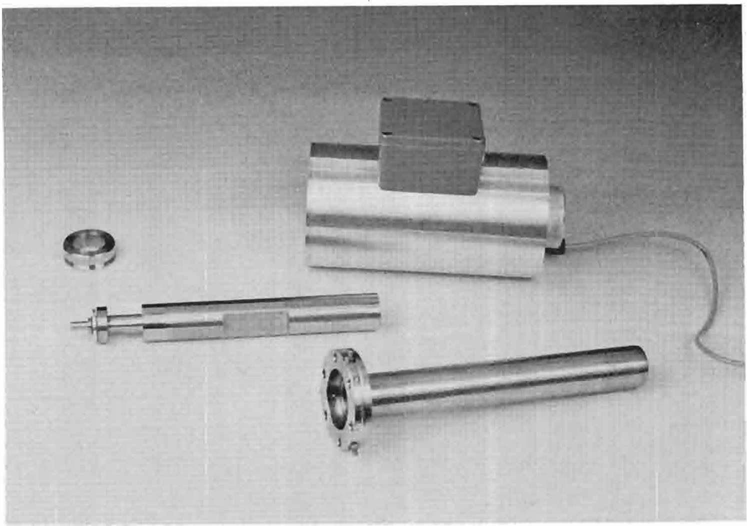

Fig. 3. Vacuum tube, rotor and stator packet
of the chopper type I

Fig. 3 demonstrates, that the bearing-motor packet may easily be removed as mentioned above. The rotor may be pulled out of the tube very quickly, if a change of the chopper disc is necessary for example.

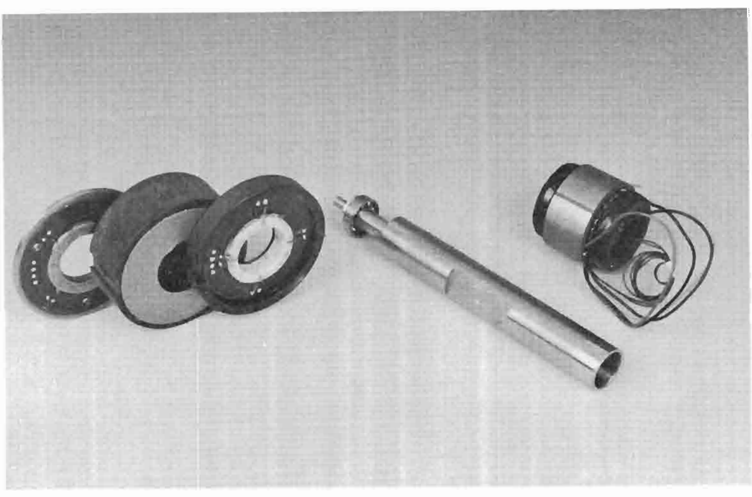

Fig. 4. Bearing and motor parts of the chopper type I

The details of the magnetic bearings are shown in fig. 4. You can see from left to right the magnetic flux sensor, the permanent magnets with a pair of iron sheet discs in front of it, the electromagnet, the rotor and the motor. The iron discs have excentric holes and compensate the rotor wheight by field deformation, if the chopper is arranged horizontally. The centric position of the rotor will be stabilized by the segmentated electromagnet, controlled by the signal of the flux sensors.

The total electronic supply of the choppers type I and II is integrated in one common electronic unit, which contains the DC power supply, the motor power supply, the operation status control unit, two control units of the magnetic bearings and a floating battery power supply, which is sufficient for a complete run down of the chopper.

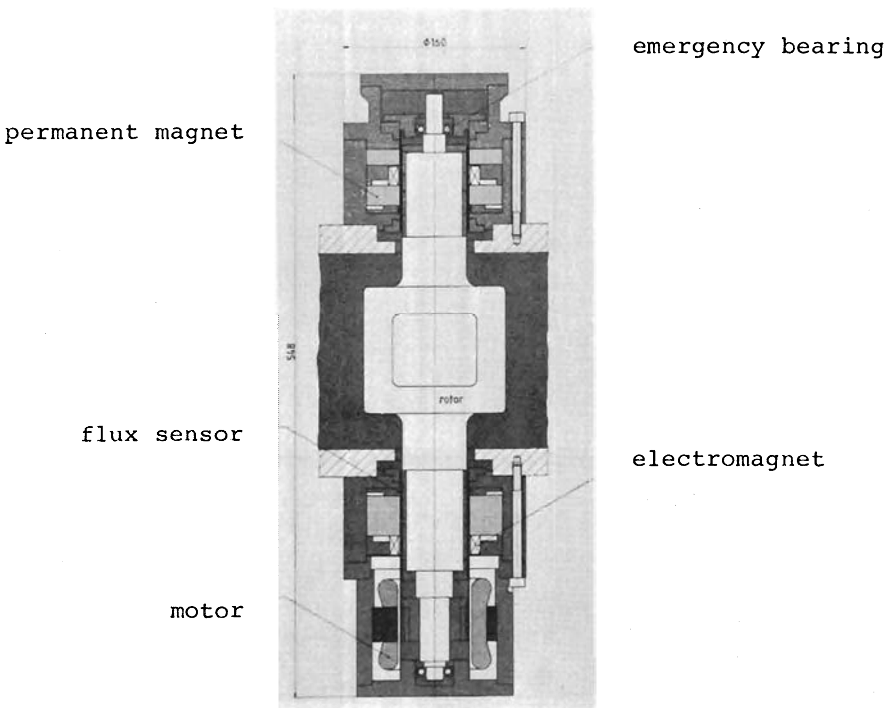

Fig. 5. Cross section of the chopper type II

The following gives some details of the bigger chopper type II (fig. 5 to 7). Fig. 5 shows a cross section of this chopper and fig. 6 a total view.

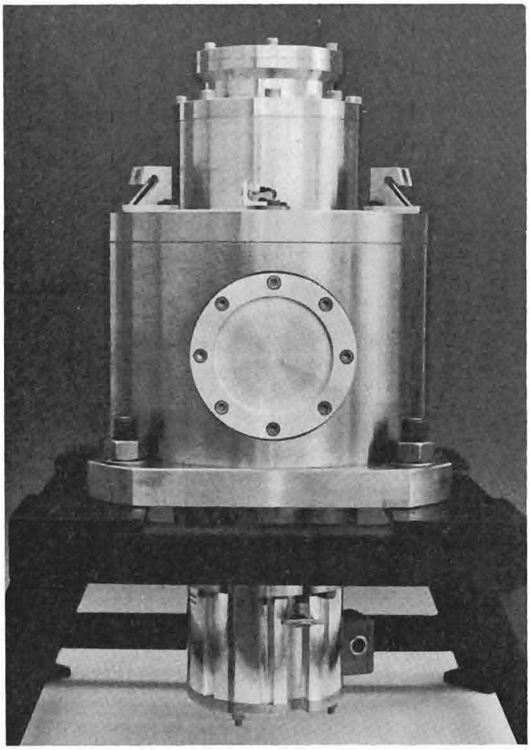

Fig. 6. Total view of the chopper type II

On fig. 7 you can see the arrangement of the two magnetic bearings and the rotor. As the main body consists of aluminium, some rings of ferro magnetic material are fitted to the rotor.
The details of the magnetic bearing of the chopper type II are very similar to the parts of type I (fig. 4) but of greater size. As type II has been realized only in a vertical arrangement, the pair of excentric iron discs is not necessary.

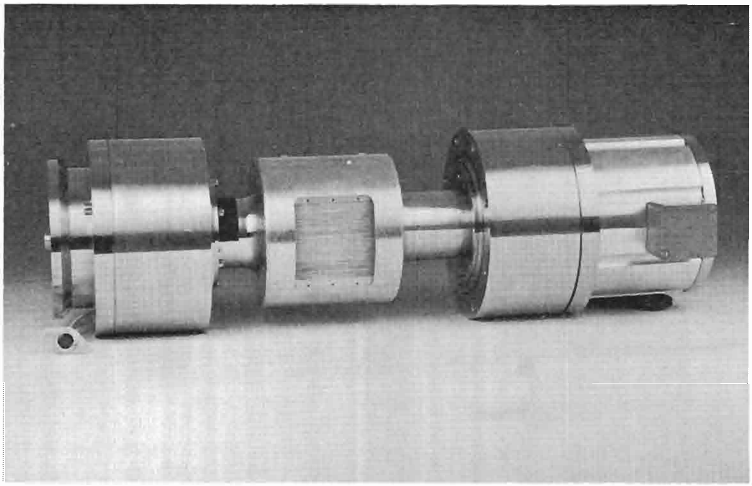

Fig. 7. Rotor/Bearing subassembly of the chopper type II

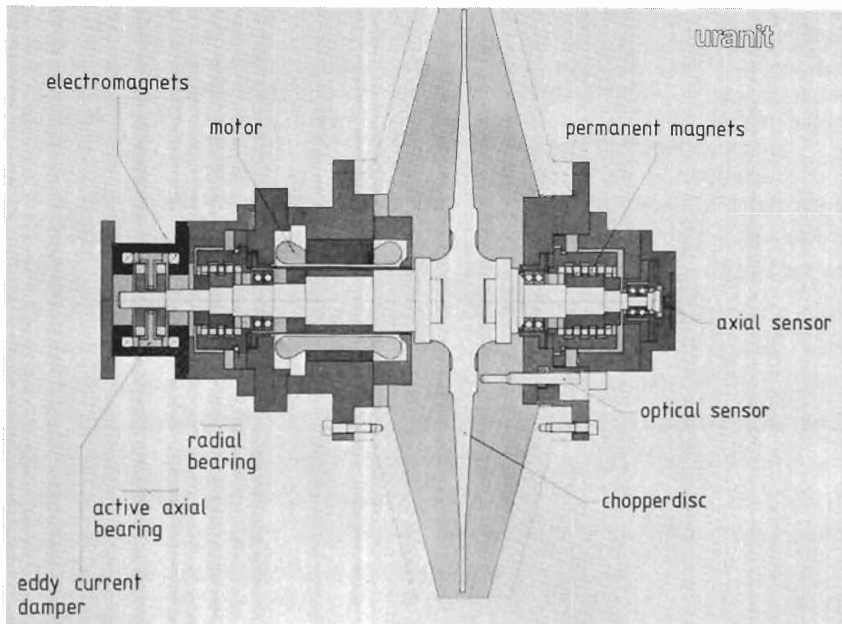

Fig. 8. Cross section of the chopper type III

The third chopper type is shown in fig. 8. This type is now built for the HMI with some modifications. The changes concern the arrangement of the bearings and the chopper disc, which shall be mounted in an overhung position. This is necessary, because the choppers shall be used in pairs with contercurrent rotating discs close together.
The most important data of the three types of chopper bearings are presented in table 1. The speed of rotation and the rotor weight in this table are not ultimate figures but typically realized values.

Tab. 1: Characteristic data of magnetic bearings

	Type I	Type II	Type III
Radial bearings	active	active	passive
Axial bearing	passive	passive	active
Arrangement	vertical/horizontal	vertical	horizontal
Rotor weight	1 kg	8 kg	12 kg
Bearing gap	3,5mm radial	2,0mm radial	1,0mm axial
Rotor speed	≦ 1000 Hz	600 Hz	333 Hz
Phase accuracy:			
per convolution	±0,025°	±0,01°	±0,01°
max.deviation	±10°	±0,01°	±0,01°
Radial bearing stiffness	160 000 N/m	100 000 N/m	210 000 N/m
Cooling medium	air	air	air