United States Patent [19]

Katagiri et al.

[11] **3,818,394**

[45] **June 18, 1974**

[54] **ELECTRON LENS FOR ELECTRON MICROSCOPE AND THE LIKE**

[75] Inventors: **Shinjiro Katagiri,** Katsuta-shi; **Susumu Ozasa,** Kodaira-shi; **Hirokazu Kimura,** Koganei-shi; **Toshio Doi; Hiroshi Kimura,** both of Tokyo-to, all of Japan

[73] Assignee: **Hitachi, Ltd.,** Tokyo-to, Japan

[22] Filed: **June 9, 1967**

[21] Appl. No.: **644,846**

[30] **Foreign Application Priority Data**

June 10, 1966 Japan 41-37085

[52] **U.S. Cl.** **335/210,** 335/216, 250/396

[51] **Int. Cl.** **H01f 7/00**

[58] **Field of Search** 335/210, 211, 212, 213, 335/214, 216; 250/49.5

[56] **References Cited**

UNITED STATES PATENTS

2,624,022	12/1952	Wolff	335/210
3,008,044	11/1961	Buchhold	335/210 X
3,351,754	11/1967	Dietrich et al.	335/210 X

Primary Examiner—George Harris

Attorney, Agent, or Firm—Craig & Antonelli

[57] **ABSTRACT**

An electron lens assembly having a diamagnetic shielding member or members inserted in the central opening of a hollow, cylindrical superconducting coil, at least one of the members is movable therein along the axis of the electron beam whilst the coil and member or members are kept in a superconducting state. By this arrangement, the focal length of the lens assembly can be changed by the variation along the axis of the coil of the distribution of magnetic field strength produced by the coil.

9 Claims, 4 Drawing Figures

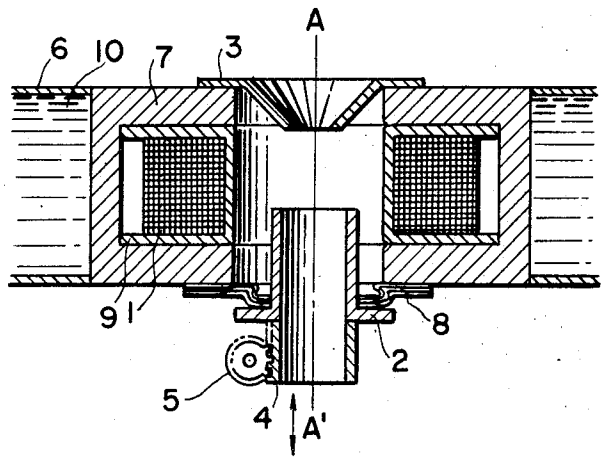


FIG. 1

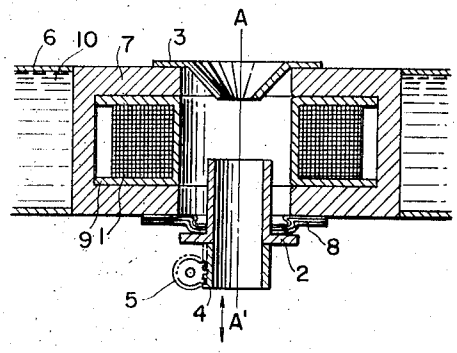


FIG. 2

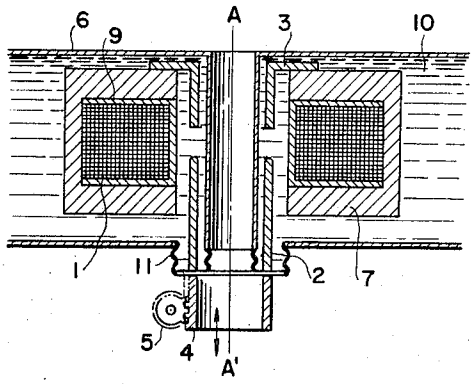


FIG. 3

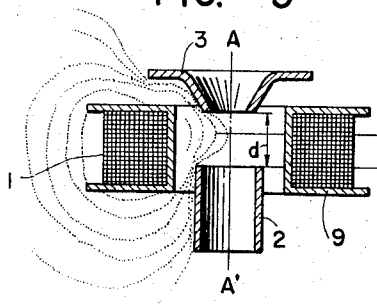
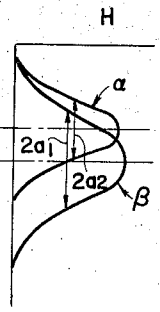


FIG. 4



ELECTRON LENS FOR ELECTRON MICROSCOPE AND THE LIKE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an electron lens assembly for electron microscopes and the like.

More specifically, the invention relates to an electron lens assembly whose focal length can be varied, and which is comprised by a hollow, cylindrical superconducting coil and a movable diamagnetic shielding member or members.

2. Description of the Prior Art

Conventional electron lenses, for example those described in the textbook "The Electron Microscope", by E. F. Burton, published by Reinhold Publishing Co., 1948, p. 159–174, have drawbacks in that the focal length of such known lenses is not readily changeable. For example, when such a known electron lens is used with an electron microscope, the electron beam once focused on an object plane will come out of focus whenever the visual field is shifted or even when the accelerating voltage of the electron beam is only slightly varied. It therefore becomes necessary to readjust the focal length after every such shifting or variation. This necessity cannot be easily met by conventional electron assemblies.

SUMMARY OF THE INVENTION

It is a primary object of the present invention to provide an electron lens assembly which is readily changeable in focal length.

Another object of the invention is to make the focal distance of an electron lens assembly changeable by the provision of a movable diamagnetic shielding member of members which render the distribution of magnetic field strength produced by the coil variable.

Another object of the invention is to provide a very thin and small shielding member or members and prevent magnetic saturation of said member through the use of diamagnetic material in the fabrication of the member.

Still another object of the invention is to reduce the inside diameter of a coil for producing a magnetic field and thereby concentrate the magnetic field within a limited space.

A further object of the invention is to permit image focusing, changing of magnifications, or the like by the movable construction of the member or members provided for shielding purposes.

To realize these objects, an electron lens assembly according to the present invention comprises a superconducting coil having a central opening, one or two shielding members of diamagnetic material inserted in the central opening of the coil symmetrically with respect to the axis of electron beam, means to move at least one of the diamagnetic members along the axis of electron beam, and means for maintaining the said coil and member or members in a superconducting state.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 are diagrammatic views exemplary of the constructions of two embodiments of the invention; and

FIGS. 3 and 4 are, respectively, a diagrammatic view and a graph illustrative of the performance of the above embodiments.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring specifically to FIG. 1, a superconducting coil 1 is formed from superconducting wire in the shape of a hollow cylinder having a central opening. The axis A–A′ of the central opening is designed to be aligned with the axis of an electron beam from a suitable electron source. An iron cover 9 having a U-shaped cross section surrounds the inner peripheral surface of the coil 1.

Cylindrically-shaped members 2 and 3 are provided for shielding purposes and are made of a diamagnetic material such as niobium-zirconium alloy. The members 2 and 3 are inserted in the hollow of the coil 1, symmetrically with respect to the center axis of coil 1 and the axis of electron beam A–A′. The member 2 is so constructed that it can be moved up and down along the axis A–A′ by means of a rack 4 and pinion 5. Member 2 is connected to one face of an annularly-shaped magnetic core member 7 through a flexible and thermally conductive metal foil 8, while the cylinder 3 is secured fixedly to the remaining opposite face magnetic core member 7. A tank or reservoir 6 surrounds the core member 7 and is filled with liquid helium 10, which serves to cool the coil 1 and the diamagnetic members 2 and 3 to a very low temperature and maintain them in superconducting state.

The focal length of an electron lens is determined by the distribution of magnetic field strength along the axis A–A′ and the maximum value H_{max} thereof. It thus follows that, if either the distribution or maximum value is made variable, the focal distance can be made changeable. According to the present invention, the distribution is made variable by varying the width of the expanse of the distributed magnetic field strength along the axis A–A′. For measurement purposes, one half of the width obtained when the maximum value H_{max} is halved, is taken and is herein expressed as a.

In FIG. 1, flow of a current through the superconducting coil 1 will produce a magnetic field as indicated by dotted lines in FIG. 3, and a distribution of magnetic field strength will result along the axis, as represented by a curve a in FIG. 4.

If it is assumed that the diamagnetic shielding members 2 and 3 are omitted, the distribution of magnetic field strength will be as indicated by the curve β. As can be seen from FIGS. 3 and 4, the use of the shielding members 2 and 3 enables the coil 1 to produce a magnetic field which is concentrated within the space between the two members 2 and 3 and permits other parts to be shielded. It is also clear that the width a_2 is less than the width a_1 where the shielding members are omitted, and that the width a_2 varies with changes of the distance d between the members. Thus, as the pinion 5 is driven, the member 2 is moved upward or downward to provide a magnetic field having a desired width a_2, and accordingly the focal length of the electron lens can be varied.

In FIG. 2 there is shown another embodiment of the invention wherein the shielding members 2 and 3 of diamagnetic material are directly encased in the liquid helium tank 6. With this arrangement, the members can be more easily kept at a very low superconducting

temperature than in the embodiment shown in FIG. 1 while the member 2 can be moved up or down by way of a bellows 11.

While two shielding members 2 and 3 of diamagnetic material, in a vertical and symmetrically arranged construction are employed in the embodiments described above, they may be replaced by one upper or lower shielding member which is movable. Even when two shielding members are used, only one member, upper or lower, is required to be movable. Of course it is possible to make both movable. Further, the members are not limited to the cylindrical form shown but may have any other suitable shape. In brief, it will be understood that they have only to be diamagnetic members as such, whatever the configuration.

As described hereinabove, the electron lens according to the invention uses a shielding member or members of diamagnetic material which will not permit magnetic flux to pass therethrough and will not invite magnetic saturation. For this reason, the invention has the additional advantage in that the shield member or members can be very thin and small in size. This small size in turn enables the coil to be reduced in inside diameter and the magnetic field thereof to be concentrated in a limited space.

Having described two embodiments of an electron lens assembly constructed in accordance with the invention, it is believed obvious that other modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that changes may be made in the particular embodiments of the invention described which are within the full intended scope of the invention as defined by the appended claims.

We claim:

1. An electron lens assembly comprising a coil formed from superconducting material and defining a central opening the center axis of which is designed for alignment with an electron beam path, at least one shielding diamagnetic member supported within the central opening of the coil and surrounding the center axis thereof, means for moving the diamagnetic member relative to the coil, and means for maintaining said coil and said member in a superconducting state.

2. An electron lens assembly according to claim 1 wherein said diamagnetic member is axially movable along the center axis of the coil for adjusting the focal length of lens assembly.

3. An electron lens assembly according to claim 2 wherein the diamagnetic member is symmetrically-shaped with respect to the center axis of the coil.

4. An electron lens assembly according to claim 1 wherein there are at least two shielding diamagnetic members, one supported at each end of the central opening of the coil and surrounding the center axis thereof, at least one of the diamagnetic members being axially movable relative to the center axis of the coil.

5. An electron lens assembly according to claim 4 wherein the coil and central opening are cylindrically-shaped and the shielding diamagnetic members are symmetrically-shaped relative to the center axis.

6. An electron lens assembly according to claim 5 further including an annular magnetizable core member having a U-shaped cross section surrounding said coil and having the center axis thereof aligned with the center axis of the coil, one of said shielding diamagnetic members being secured to one side of the central opening in the annular core member and the other shielding diamagnetic member being movably supported on the remaining side, and a reservoir of superconducting refrigerant surrounding said annular magnetizable core member.

7. An electron lens assembly according to claim 6 wherein the movable shielding diamagnetic member comprises an open ended cylindrically-shaped member having its center axis aligned with the center axis of the coil and having a rack formed on one end thereof, a pinion coacting with the rack on the diamagnetic member, and means for movably supporting the shielding diamagnetic member on the annular magnetizable core member in axial alignment therewith.

8. An electron lens assembly according to claim 7 wherein the movable supporting means comprises a thermally conductive flexible metal foil secured between the annular magnetizable core member and the cylindrically-shaped movable diamagnetic shielding member.

9. An electron lens assembly according to claim 7 wherein the movable supporting means comprises a flexible bellows filled with superconducting refrigerant from the reservoir and wherein the reservoir surrounds the entire assembly with the exception of a central open passageway coaxially aligned with the center axis of the coil and in alignment with the electron beam path and with the exception of the rack portion of the movable diamagnetic shielding member, the bellows being secured between said rack portion and the walls of the reservoir.

* * * * *