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HOLLOW HEAVY PRIMARY ION SOURCES FOR EBIS

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Technical Note

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Introduction

It has been said that no accelerator is better than its injector. At present, it is not clear whether there is such an analogy to large output, low emittance EBIS devices and their primary ion sources. However, the general consensus is that an ideal primary ion source for EBIS does not yet exist.[1]

An alternative primary ion injection method for EBIS, utilizing sources that are physically hollow, is described in this note. A hollow ion source is to be placed between the electron gun and the EBIS trap in order to co-inject (with an electron beam) a space charge neutralized ion beam.

Some Examples of Hollow Sources

Figures 1, 2, and 3, are schematics (roughly to scale) of possible hollow primary ion sources that can be actually fitted on SuperEBIS. In warm bore EBIS devices with long electron gun to trap gap, the use of other sources including plasma ion sources may be possible. In sources with multi-Ampere electron beams, the electron beam can be used to scrape off an annular target by the impression of a pulsed poloidal electric field, on the electron beam, which would force it to expand radially.

A hollow zeolite ion source is shown in Figure 1. It is a simple source. The heaviest ion species that can be delivered from such a source is thallium. Since the cathode is basically a solid state emitter, the hollow configuration of the cathode will have no bearing on the source operation (other than the beam profile).

In Figure 2, a diagram of a hollow cathode MeVVA is shown. MeVVA (which is the acronym of metal vapor vacuum arc) is a prolific generator of highly ionized metal plasma, from which metallic ions are extracted. MeVVAs have been developed for use as sources of metallic ions. A generic MeVVA consists of a series of electrodes, usually concentric, that are separated by ceramic insulators. The usual configuration constitutes a solid electrode, from which material is vaporized, followed by a trigger electrode, an anode, a suppressor, and an extractor. Triggering of the vacuum arc is accomplished by applying a short high voltage pulse between the trigger electrode and the cathode across an insulating surface. Discharge occurs due to formation of "cathode spots", micron-sized spots on the cathode surface characterized by extremely high current densities. Cathode material is vaporized and ionized, and a plasma plume forms. Arc currents of 10s to 100s of amperes is the usual range of discharge currents for MeVVA ion sources depending on their size and application. These ion sources vary in size, extracted current, and pulse length. The beam extraction area ranges from 0.05 cm to 2000 cm, while the maximum extracted current varies among the sources from 10 mA to 3.5 A. Most MeVVAs operate with pulse lengths of 0.1 to a few msec, although there are a few MeVVAs that operate dc. A good general reference on MeVVAs is Ion Brown's (original developer of MeVVAs) review in The Physics and Technology of Ion Sources, edited by I.G. Brown (Wiley, New York, 1989), p. 331.

Although the vast majority of MeVVAs have solid cathodes that are shaped like rods, there are at least two MeVVAs whose cathodes are hollow: one is being operated by Marrs' group at LLL,[2] while the second was developed by Batalin, et al., from ITEP, Moscow.[3] The LLL source operates with a reliability that is higher than that of conventional MeVVAs (it fires every shot), and it has generated various metallic ions including uranium. The source shown in Figure 2 contains features of both sources.

A diagram of a laser ablation source is shown in Figure 3. A laser beam pulse is to be focused upon a surface of the material containing the desired ions. The surface material is then explosively ablated as a dense plasma plume that expands along the direction of greatest hydrodynamical pressure gradient and fills the compression tube. Such a source can deliver ions of any solid material.

Common features of these primary ion sources, shown in Figures 1, 2, and 3, are ion repellers to prevent ions from streaming into the electron gun, and electron suppressors to prevent slow, plasma electrons from entering the EBIS trap or the electron gun (not always shown). Prevention of slow electron trapping can be done with a double asymmetric trap, e.g., during the confinement period, an asymmetric potential can be impressed on drift tubes number 1 and number 15 of SuperEBIS. This potential has to be higher than that applied to drift tubes number 2 and number 14. Slow electrons can cause instabilities in the trap if not eliminated.

Advantages of Proposed Injection Scheme

This method of injection has a number of advantages over the schemes presently used:

1. Full acceptance of the primary ion beam instead of only a small solid angle. An EBIS RHIC preinjector will have a trap capacity that is a factor of 20 larger than today's state-of-the-art EBIS, hence it will need a factor of 20 more ions to be filled with. It also minimizes deposition of radioactive nuclei on various source surfaces.

2. As a consequence of full utilization of the injected beam, the primary sources do not need to be driven hard, resulting in a long lifetime.

3. No space charge problems.

4. Elimination of lens problems due to various electron and extracted ion beam optical elements that are encountered by the injected primary ions.

5. Primary ions can be injected with a very low energy. Therefore, the trap can be kept close to ground potential, hence, the electron energy in the trap can be minimized, thus enhancing the trap capacity.

Other Considerations

In future high current EBISs, it may be desirable to have hollow electron beams. A variation on this scheme could be very well suited for co-injection of ions through the center of the hollow electron beam from conventional (not hollow) ion sources.

However, some additional issues will need to be addressed. Although plasma propagation (compensated ion and electron beam) should work well during the ion injection part of the EBIS cycle, adjustment of some electron beam parameters may be needed during some parts of the cycle. This will require some analysis and testing.

References

1. B. Visentin's review of ion sources for EBIS injection, presented at the Sixth International Symposium on Electron Beam Ion Sources and Their Applications.

2. R. Marrs, private communication, 1988.

3. V.A. Batalin, Y.N. Volkov, T.V. Kulevoy, S.V. Petrenko, ITEP, Moscow, Preprints 18-93 (1993) and 33-94 (1994).

Figure Captions

Figure 1. Hollow ion zeolite source. Shown are the hollow cathode (zeolite button) followed by a hollow anode (ion extractor). Electrode A is an ion repeller.

Figure 2. Schematic of a hollow MeVVA ion source. The electrode between the extractor and anode is an electron suppressor. Electrodes A and B are ion repeller and electron suppressor, respectively.

Figure 3. Diagram of a laser ion source. Electrodes A and B are ion repeller and electron suppressor, respectively. Electrode C is an ion extractor.

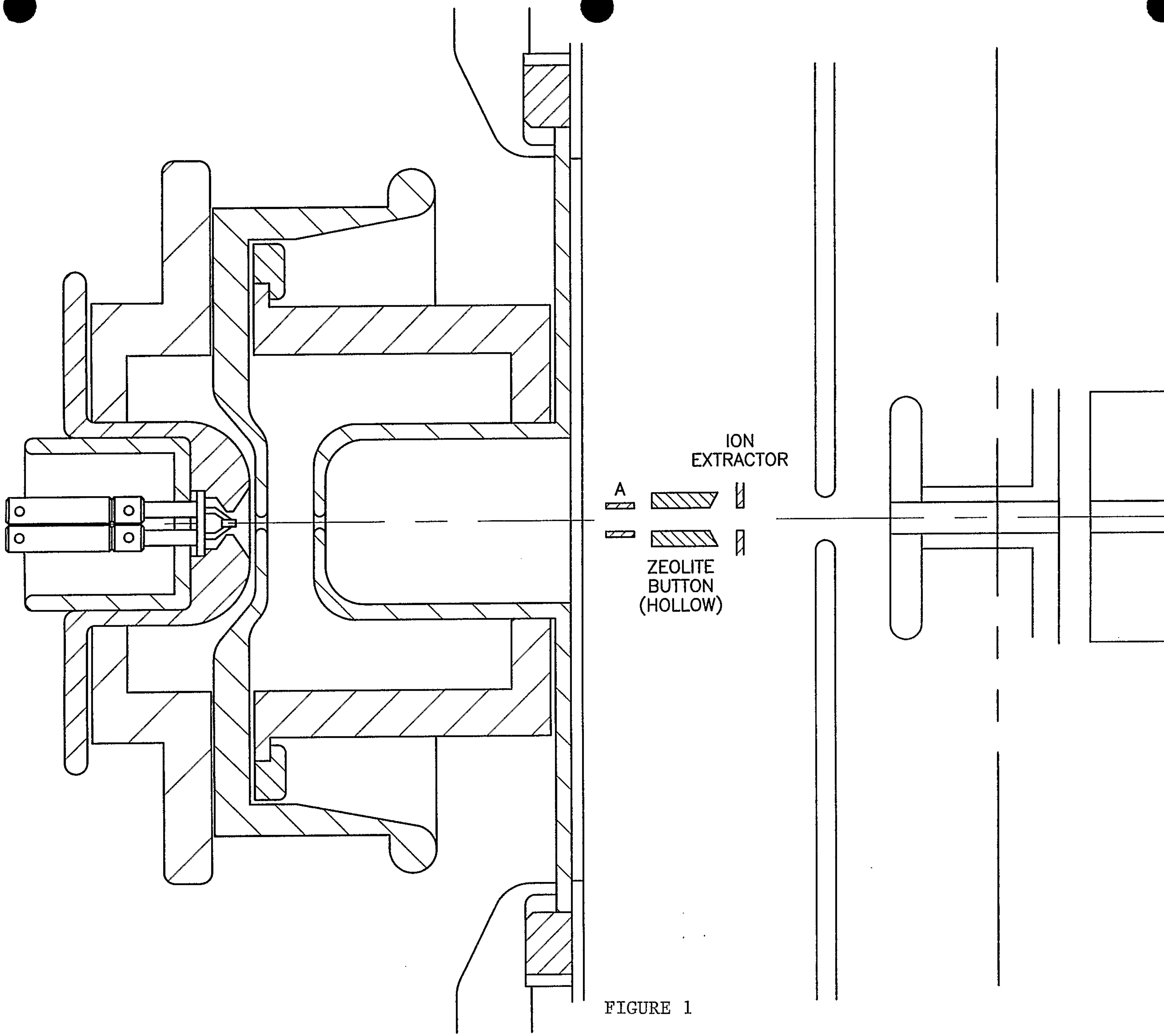

FIGURE 1

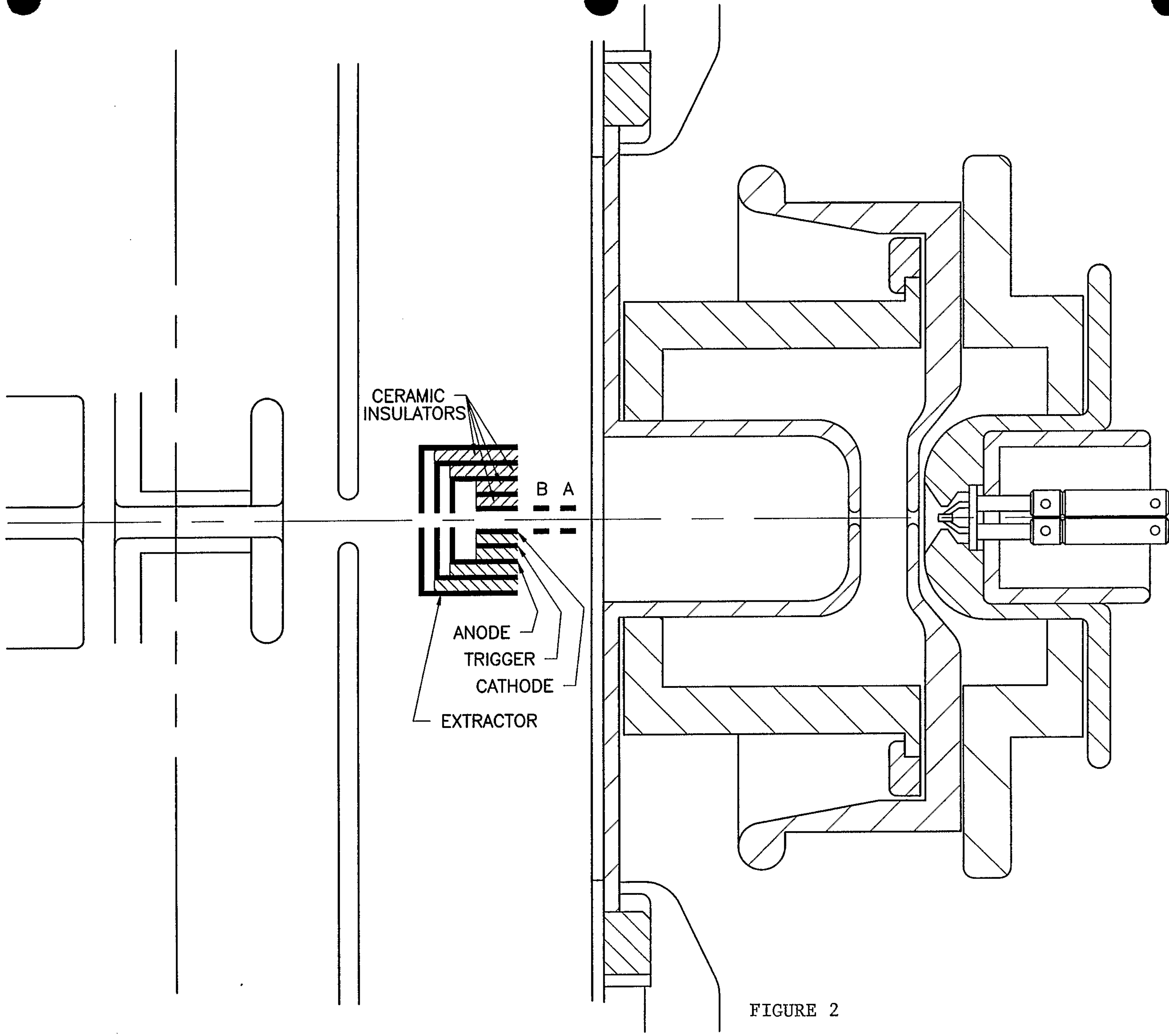

FIGURE 2

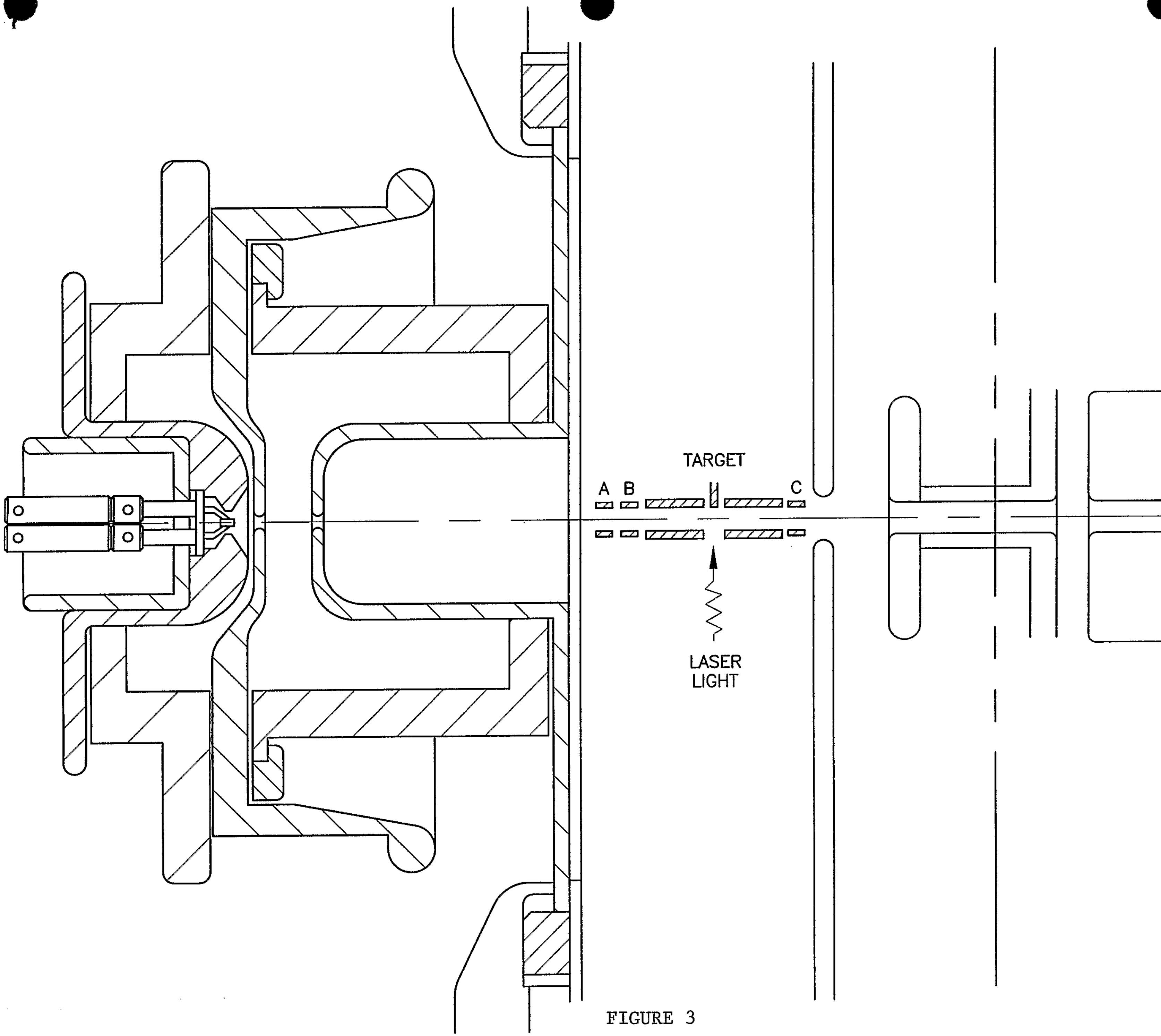

FIGURE 3