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A New High Temperature Plasma Ion Source for the TRISTAN ISOL Facility*

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Abstract

A vigorous program of ion source development at TRISTAN has led to several types of ion sources that are especially suited to extended operation at a reactor-based ISOL facility. The latest of these is a high temperature plasma ion source in which a 5 gm ^{235}U target is located in the cathode and and can be heated to 2500°C. The ion source has a lifetime of >1000 hours and produces a wide array of elements, including Pd. Off-line investigations indicate that the source functions primarily in an electron impact mode of ionization and exhibits typical ionization efficiencies of >30% for Xe.

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The TRISTAN Facility

A schematic diagram of the TRISTAN facility is shown in Fig. 1. The High Flux Beam Reactor at Brookhaven National Laboratory provides a beam with a thermal neutron intensity of $3\text{x}10^{10}$ n/cm^2/sec onto a 5g ^{235}U target which is located inside an ion source. Short-lived isotopes produced in fission are then mass separated and delivered to a selected experimental station at the end of a switching magnet. These facilities have been described recently[1,2]. To provide for maximum versatility, a variety of ion sources are used, each of which is suited to producing certain elements[1,3,4]. Each of these ion sources has an operating lifetime >1000 hours and is stable enough to run unattended.

The High Temperature Plasma Ion Source

The goal in the design of the high temperature plasma ion source was to combine the advantages of a large target and high temperature operation, as in the thermal ion source[3] with the wide variety of elements available with the FEBIAD ion source[1]. Thus, the design of the target chamber, heat shields, and electron bombardment heating was chosen to be nearly identical to that in the thermal ion source. This has an additional advantage of making production of the ion sources easier, since many parts are interchangeable. The design for the anode was inspired by that for the grid in a Bagard-Alpert ionization gauge[5].

A schematic diagram of the high temperature plasma ion source is shown in Fig. 2. The target is heated by electron bombardment from a Ta filament, which is at a potential of typically -600V relative to the target oven which is at the floating ground (50 kV) potential. With this arrangement, the target can be heated to 2500°C. The walls of the Ta target oven reach somewhat higher temperatures. Electrons are thus emitted from the walls of the oven and to some extent, the target itself. Under these operating conditions the Ta filament can become very soft. To prevent the filament from touching the target, resulting in a short circuit, it is supported by tungsten wires which protrude through the heat shields and are, in turn, attached to ceramic insulators in the cooler region outside the heat shields. This arrangement is illustrated in Fig. 3 where the target and associated components have been removed. The support wires are required to be tungsten. Earlier versions of the source used tantalum, but this caused the filament and support wires to become fused. Upon cooling or heating of the source, the filament could flex due to thermal expansion and bend until it touched the target. With tungsten as the support wires, such behavior is not observed.

The inner heat shield in Fig. 3 is made of tantalum in order to better withstand high temperatures; the others consist of a spiral of 25 μm niobium, chosen for its low neutron capture cross section. Individual turns on the spiral are separated by small "dimples" randomly scattered throughout the material. Examples of this may be seen in the lower heat shield in the photograph. The entire heat shield assembly is attached to two Mo plates by spot welding strips of niobium foil in various locations. The plates are held on three rods, separated by ceramic insulators. The assembly is floated at the filament (electron-bombardment) potential so that accidental touches will not cause short circuits. The foil strips around the insulators are to prevent the formation of conductive coatings.

The grid is constructed of a spiral of thin tungsten wire which is spot welded to thicker tantalum wire "legs" which are in turn attached to the molybdenum grid plate (number 6 in Fig. 2). The bottom of the grid (the end nearest the target) is formed by attaching thin tungsten wires across a tantalum ring which is attached to the tantalum legs.

To test the ion source operation, an off-line mass separator system was used. Xenon gas was admitted, from a calibrated leak valve, into the source via a capillary, as shown in Fig. 2. The ion beam was mass separated and could be focused onto a faraday cup located at the focal plane of the 90° separating magnet. Thus, by measuring the beam current for a particular isotope of xenon, the efficiency of the ion source under various conditions can be investigated. The results of a typical experiment are shown in Fig. 4. A wide range of total power (sum of filament and electron bombardment wattages), magnetic fields, and total pressure were investigated. In some extreme cases, the ionization efficiency for ^{134}Xe was determined to be as high as 80%, although the range of 30-40% efficiency was more common and probably better represents the conditions of on-line operation. In all cases, the curves of ^{134}Xe current versus anode voltage were similar, rising sharply between 50-100 volts, then becoming approximately independent of anode voltage thereafter. Behavior as indicated in Fig. 4 is a characteristic of electron impact ionization[5] and, therefore, this appears to be the dominant ionization mechanism of this ion source.

The on-line operation of this ion source is similar to the off-line behavior with the exception that the yields of radioactive ions tends to increase with increasing anode voltage and current, whereas in off-line tests the yield remained constant above a critical voltage. This can be understood as a target heating effect. While the ionization efficiency remains constant above a critical voltage, the increasing anode wattage provides additional target heating and increases the target efficiency. Hence, the radioactive ion yield will also increase. The source not only provides significantly higher yields for all the elements that the FEBIAD used at TRISTAN produces[1], but the high temperature plasma ion source can also produce beams of radioactive Pd. Pd was not available from the FEBIAD ion source due to the lower operating temperature. The on-line efficiency for the production of ^{116}Pd was determined to be 0.03%. Pd isotopes heavier than A=118 were not observed, in part because of insufficient experiment time, combined with little nuclear data being available. It was also evident that the hold-up time for Pd was quite long since the yield of Pd was observed to decrease with decreasing half-life much faster than the fission yield decreased.

Conclusion

An ion source based on the design of Bayard-Alpert ionization gauge and operating on the same, electron impact, mechanism was constructed. The source operates at high temperature for long periods of time and exhibits very stable operation. A wide array of elements, including Pd, produced by thermal neutron induced fission of ^{235}U was produced with high efficiency, resulting in an increased ability to study the nuclear decay of short-lived, low-yield fission products at TRISTAN.

References

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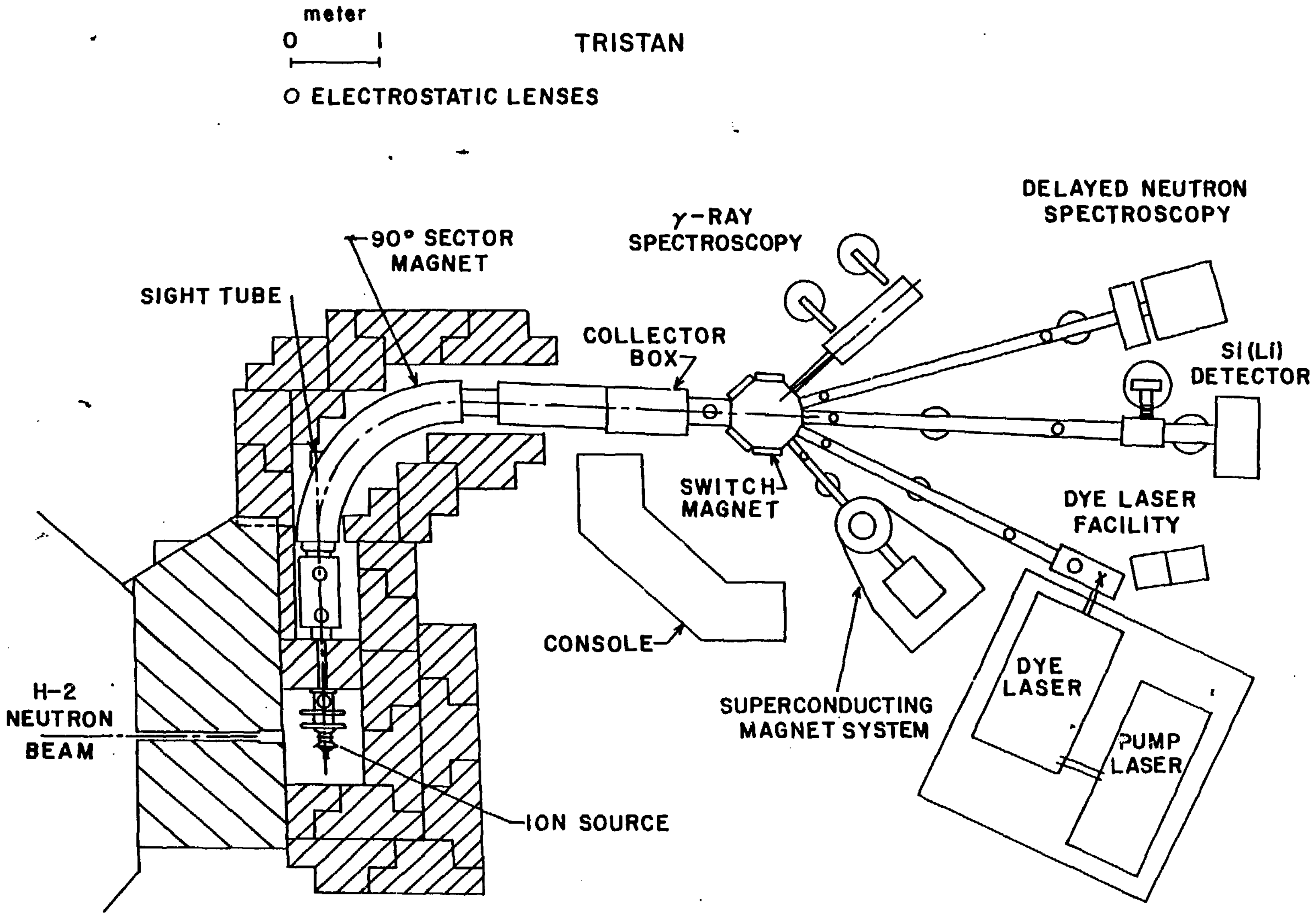
Figure Captions

Fig. 1 Schematic layout of the TRISTAN ISOL facility.

Fig. 2 1) Tantalum target oven and cathode. 2) ^{235}U on graphite cloth target. 3) Graphite target container. 4) Target retaining disc. 5) Anode grid. 6) Grid plate. 7) Shadow shielded path. 8) Exit hole. 9) Beryllium oxide anode insulator. 10) Beryllium oxide exit plate insulator. 11 and 12) Boron nitride insulators. 13) Tantalum filament. 14) Ceramic filament support insulator. 15) Filament contact. 16 and 17) Niobium heat shields. 18) Ceramic heat shield insulators. 19) Gas inlet (not used in on-line versions). 20) Base plate.

Fig. 3 Photograph of the high temperature plasma source with the target chamber and associated parts removed to show filament and heat shield construction.

Fig. 4 Behavior of the ion source under conditions typically used for on-line operation. The solid curves are referenced to the scale on the right and the dashed curve to the scale on the left.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90° SECTOR MAGNET
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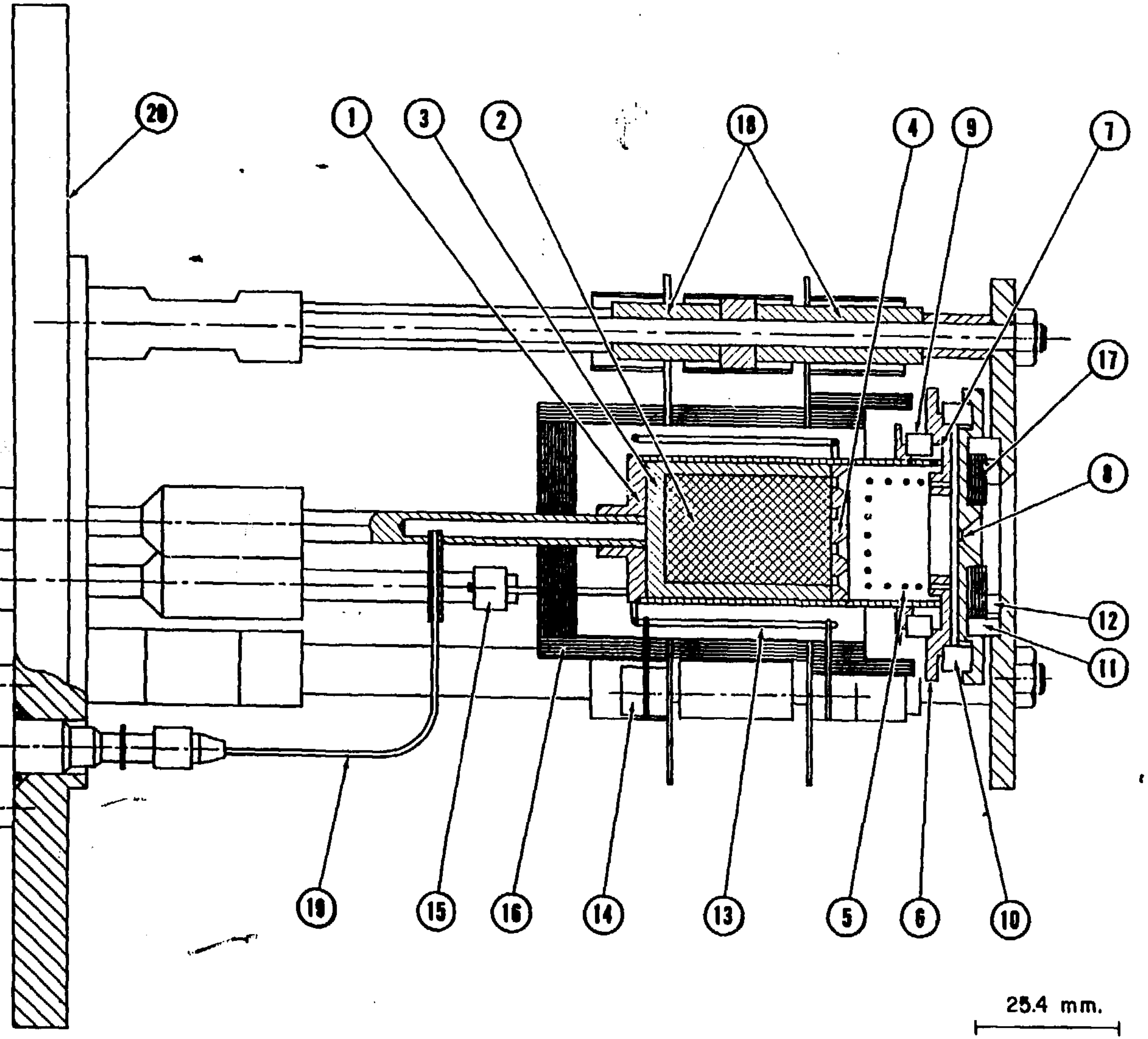

TRISTAN PLASMA ION SOURCE


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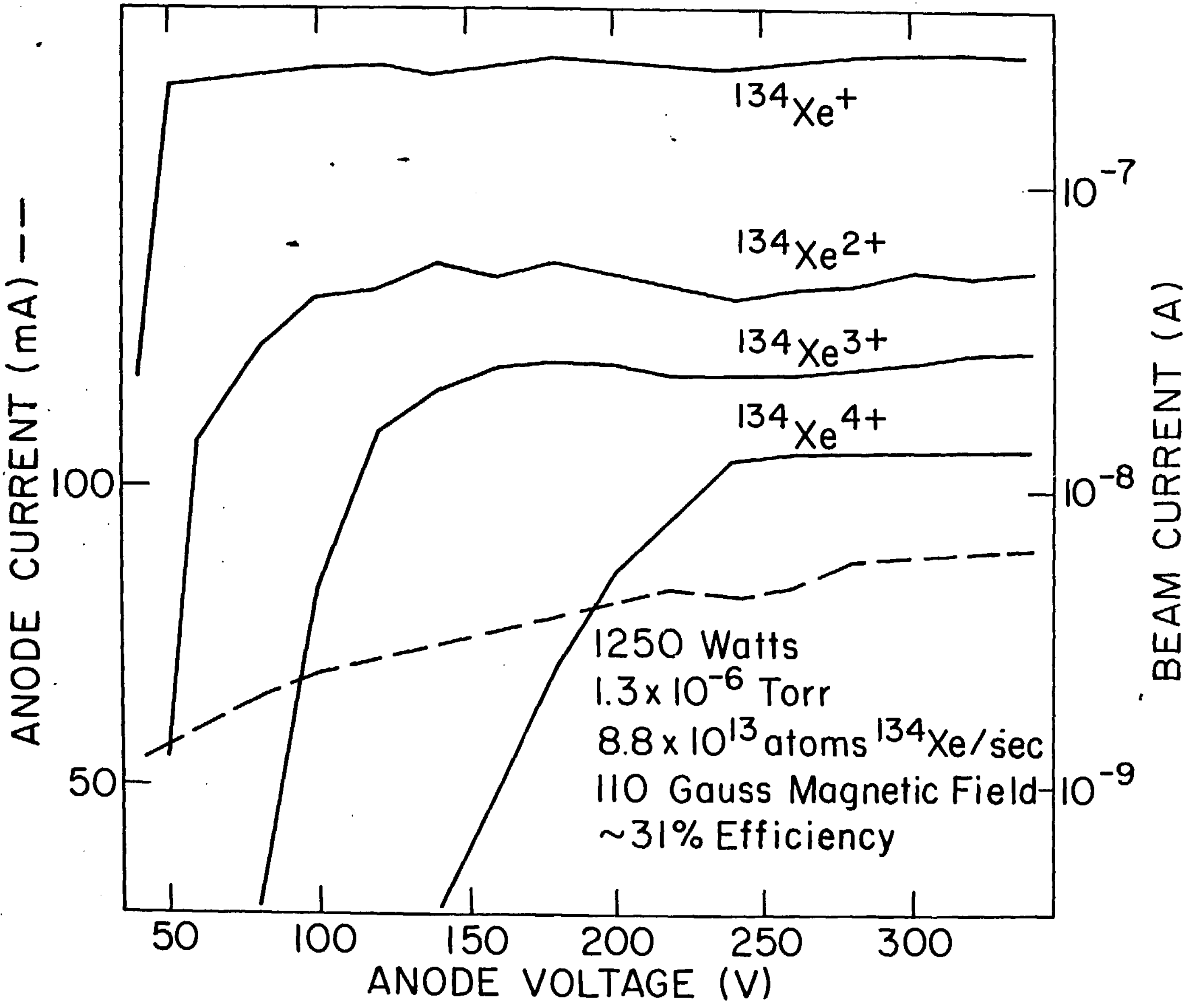
^{134}Xe^{+}
^{134}Xe^{2+}
^{134}Xe^{3+}
^{134}Xe^{4+}
1250 Watts
1.3 x 10^{-6} Torr
8.8 x 10^{13} atoms ^{134}Xe/sec
110 Gauss Magnetic Field
~31% Efficiency
ANODE CURRENT (mA) ---
100
50
BEAM CURRENT (A)
10^{-7}
10^{-8}
10^{-9}
50
100
150
200
250
300
ANODE VOLTAGE (V)