RF Positive Ion Source with Solenoidal Magnetic Field

V. Dudnikov[1,a)], R.P. Johnson[1], B. Han[2], S. Murray [2], T. Pennisi [2], C. Piller [2], C. Stinson[2], M.Stockli [2], R. Welton [2], G. Dudnikova[3]

[1]Muons, Inc., Batavia, IL 60510, USA; [2]ORNL, Oak Ridge, TN 37831, USA; [3]University of Maryland, College Park, MD- 32611-USA

Corresponding author: Vadim@muonsinc.com

ICIS 2017, CERN Geneva, October 16, 2017

The work was supported in part by US DOE Contract DE-AC05-00OR22725 and by STTR grant, DE-SC0011323.

Muons, Inc.

ABSTRACT

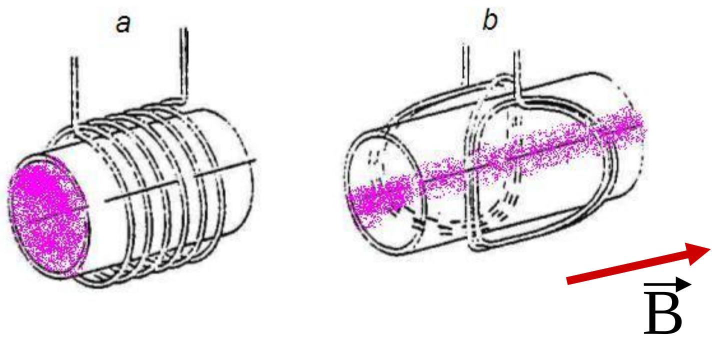
SNS SPALLATION NEUTRON SOURCE

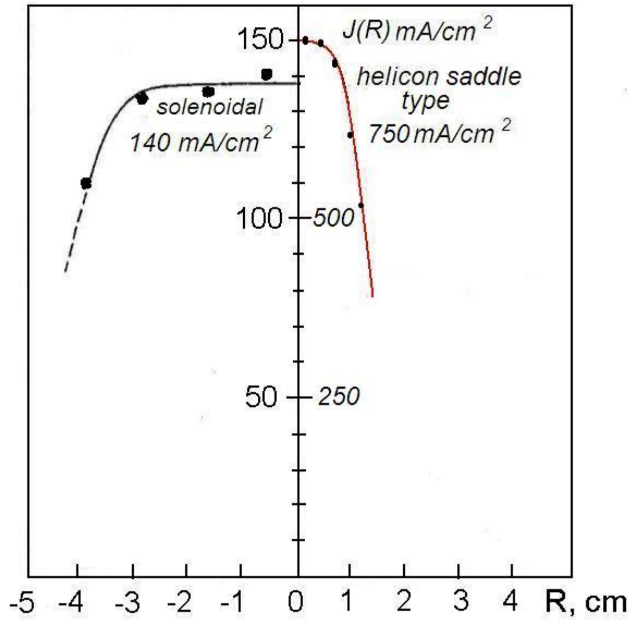
OAK RIDGE National Laboratory

- Operation of Radio Frequency positive ion sources (RF IS) with a solenoidal magnetic field are described.
- RF positive ion source with solenoidal and saddle antennas are discussed.
- Preliminary dependences of beam current and extraction current on RF power, gas flow, solenoidal magnetic field magnetic field are presented.

Efficiency of plasma generation in a Radio Frequency (RF) ion source can be increased by application of a solenoidal magnetic field. The specific efficiency of positive ion generation was improved by the solenoidal magnetic field, from 5 mA/cm^2 kW to 200 mA/cm^2 kW. Chen presented an explanation for the concentration of plasma density near the axis by a magnetic field through a short circuit in the plasma plate [*D. Curreli and F. Chen, Equilibrium theory of cylindrical discharges with special application to helicons, PHYSICS OF PLASMAS, 18, 113501 (2011).*]. Additional concentration factor can be a secondary ion-electron emission initiated by high positive potential of plasma relative the plasma plate. Secondary negative ion emission can be increased by cesiation-injection of cesium, increasing a secondary electron and photo emission.

Antennas of RF plasma generator





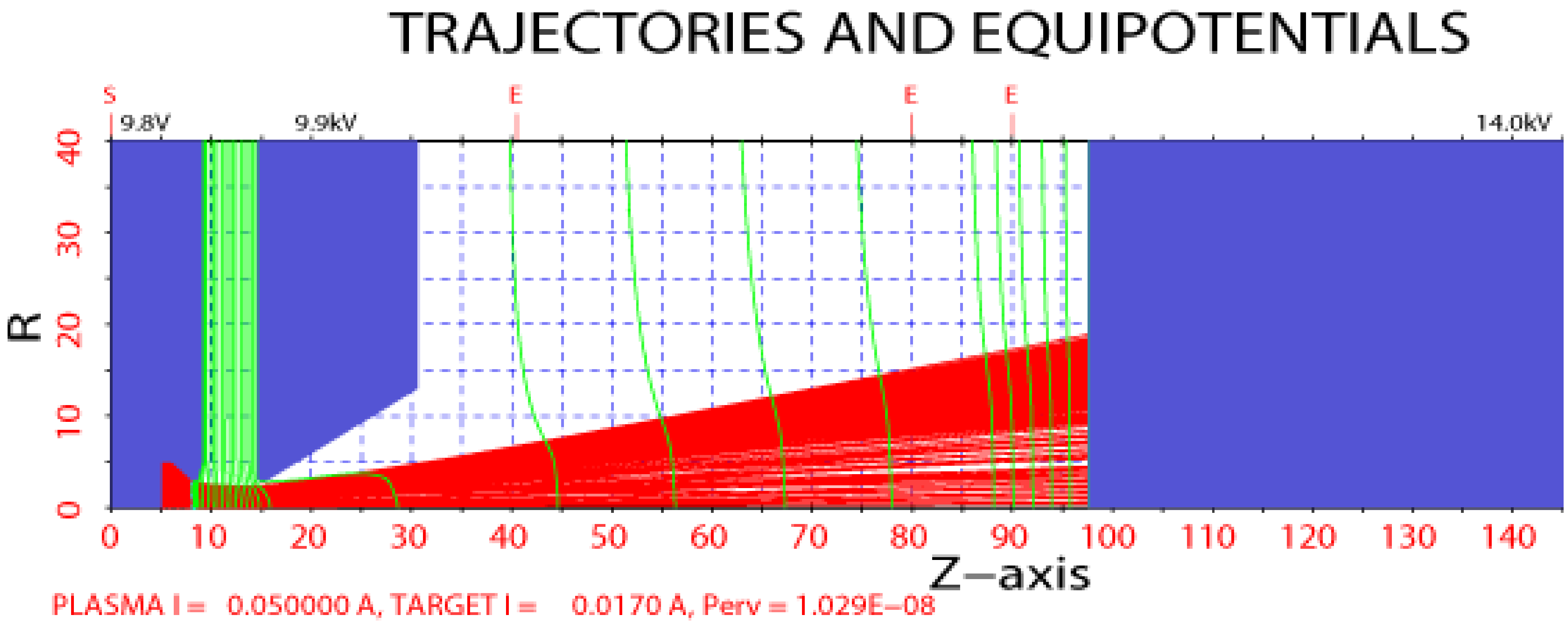
Ion flux distribution for discharge with ordinary solenoid (left) and with saddle type RF antenna (right).

RF power ~2.7 kW, RF frequency ~5 MHz, magnetic field 70 Gs

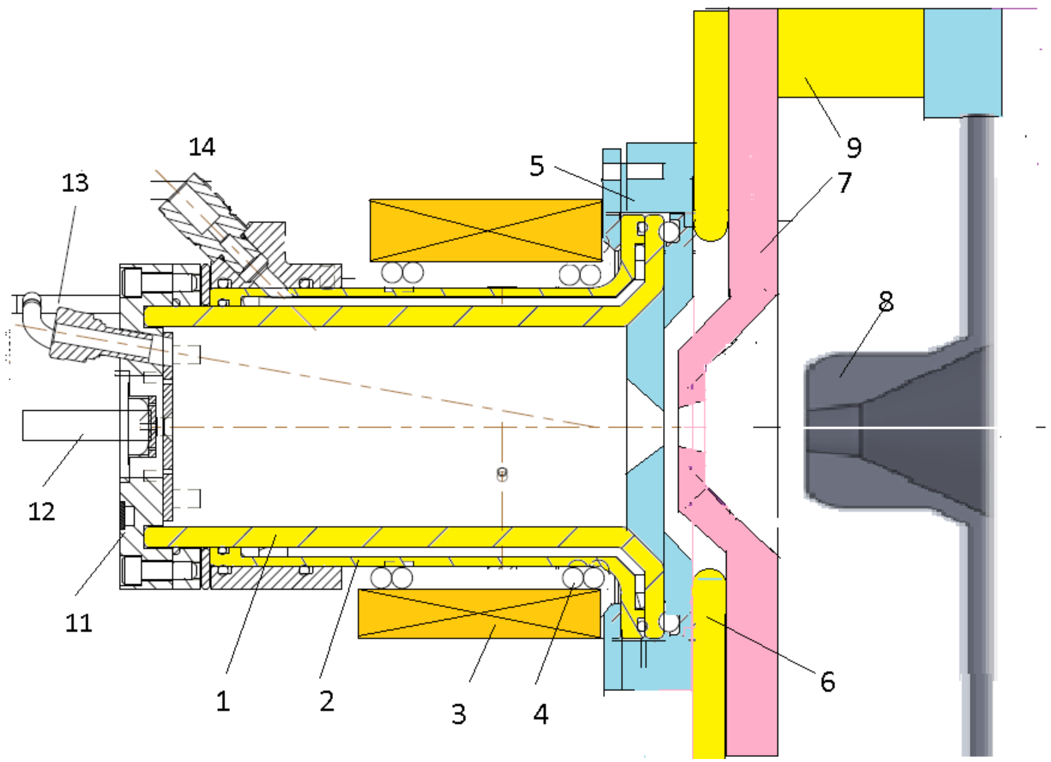
a- ordinary solenoidal antenna with plasma generation on the large radius;

b- saddle type antenna with plasma generation on the axis. Magnetic field is along the axis of cylindrical discharge chamber.

Example of beam extraction at 33 mA, Uex=9.9 kV, Uc=14 kV.

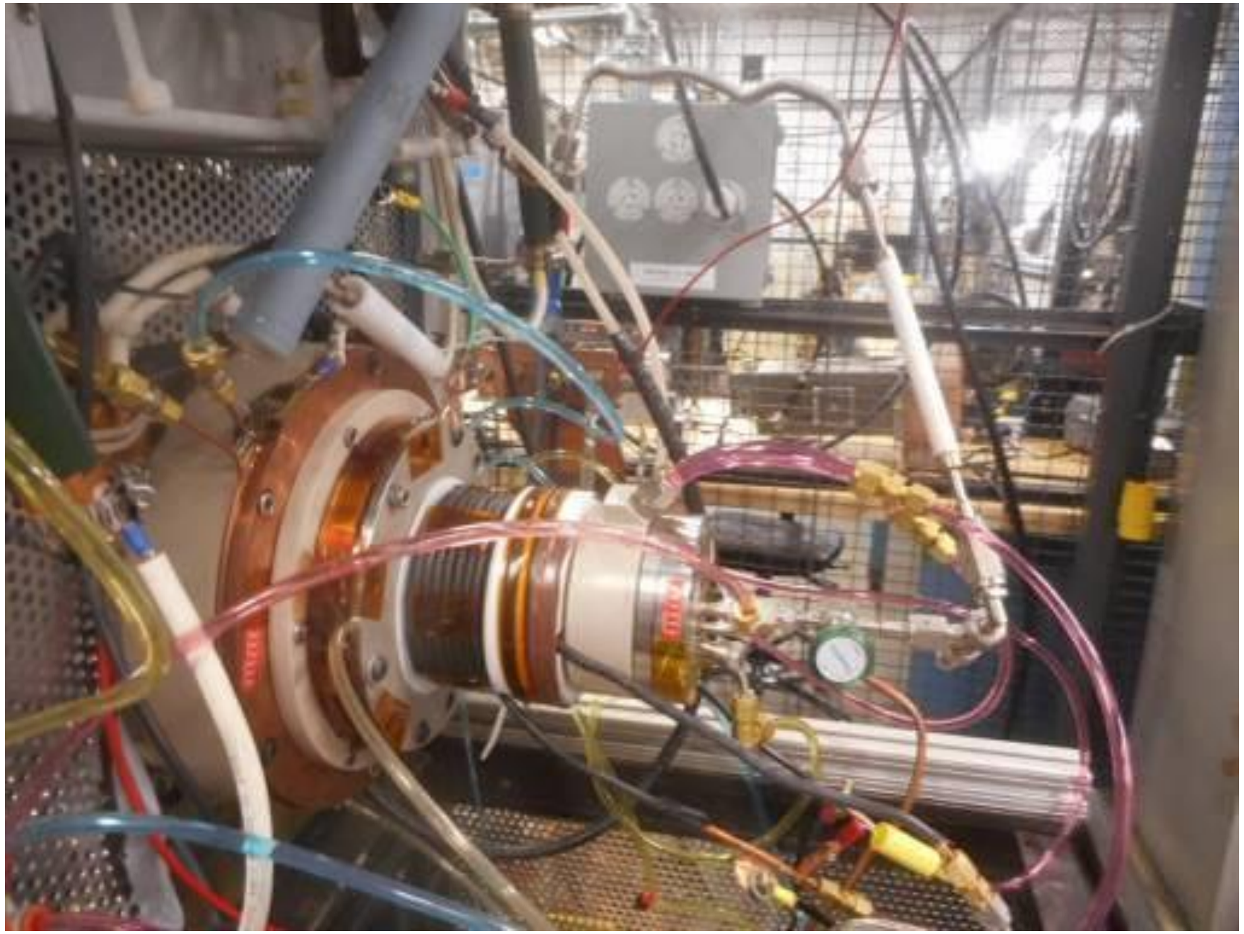


Schematic of RF discharge LV proton source with solenoidal magnetic field

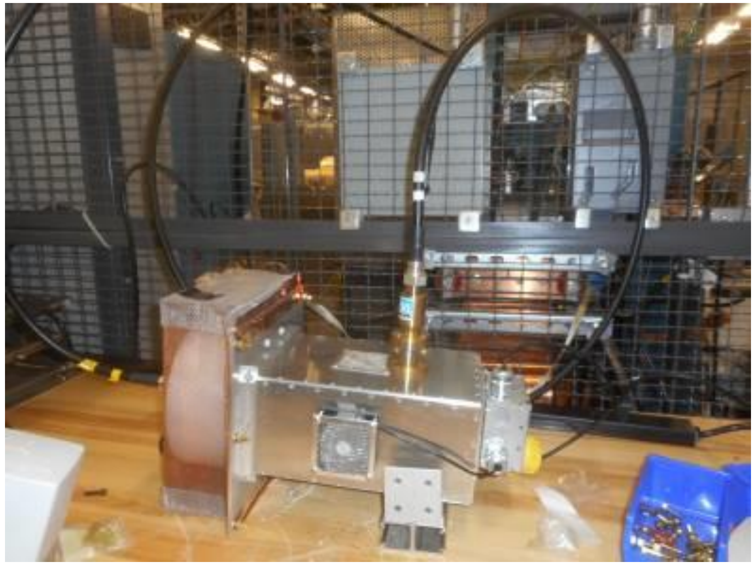


1-Gas discharge chamber (AlN), 2- cooling jacket from keep, 3- solenoid, 4- helicon antenna, 5-plasma electrode with conical collar and emission aperture, 6-extractor insulator, 7- extraction electrode, 8-grounded electrode, 9- insulator, 11- back flange, 12- gas inlet, 13- view port, 14- cooling water inlet-outlet,

Compact design of RF positive ion source with solenoidal magnetic field



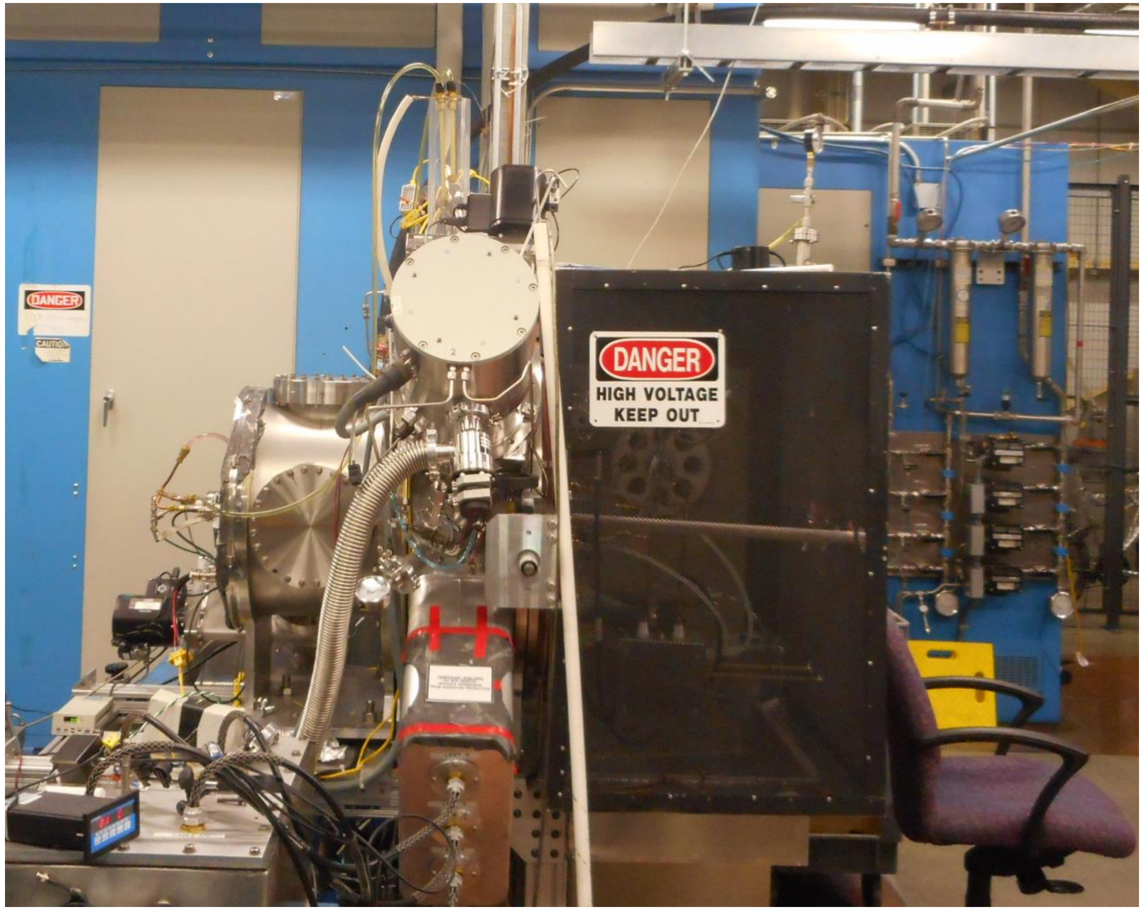
Insulating transformer



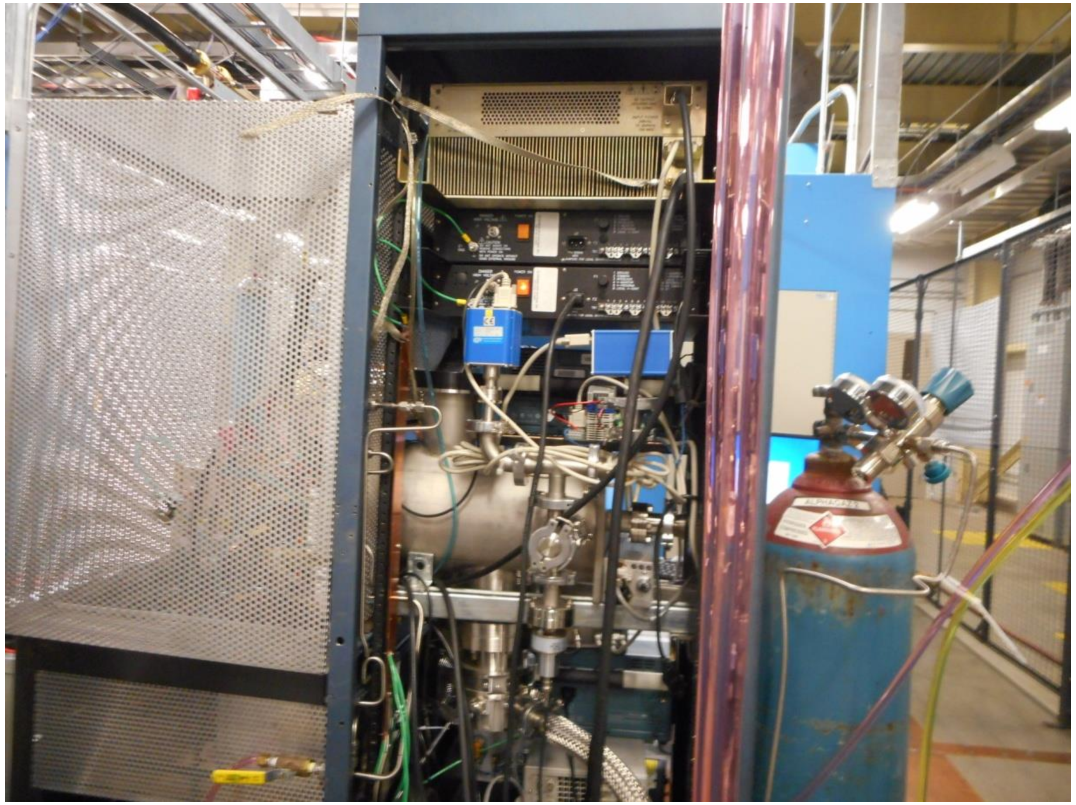
Matching network

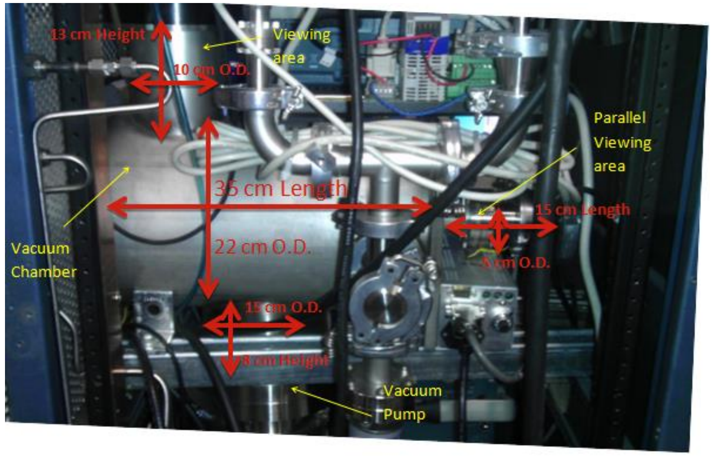
New solenoids

SNS test stand

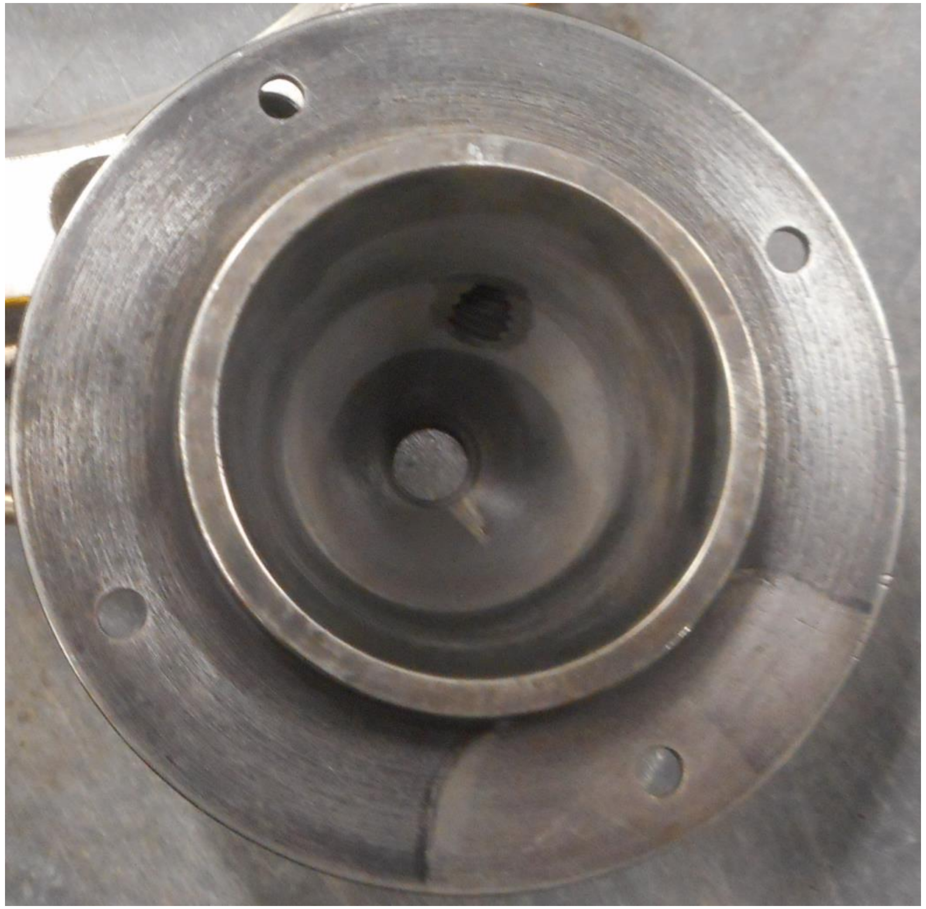


New Test Stand for SA SPS for high DF operation





- New water cooled saddle antenna and matching network;
- New water cooled solenoid ;
- New water cooled AlN chamber
- For operation with high DF (6- 100%)
- Were developed, designed, fabricated and prepared for testing in new SNS test stand.
- RF 13 MHz up to 6.5 kW
- MKS



Conical collar with a dark deposition around the emission aperture

Photo of positive ion beam extraction and collector heating by the beam. Plasma light from emission aperture is visible at a right side. Collector is heated by ion beam up to high temperature (Yellow color).

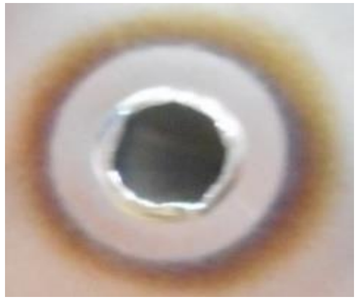
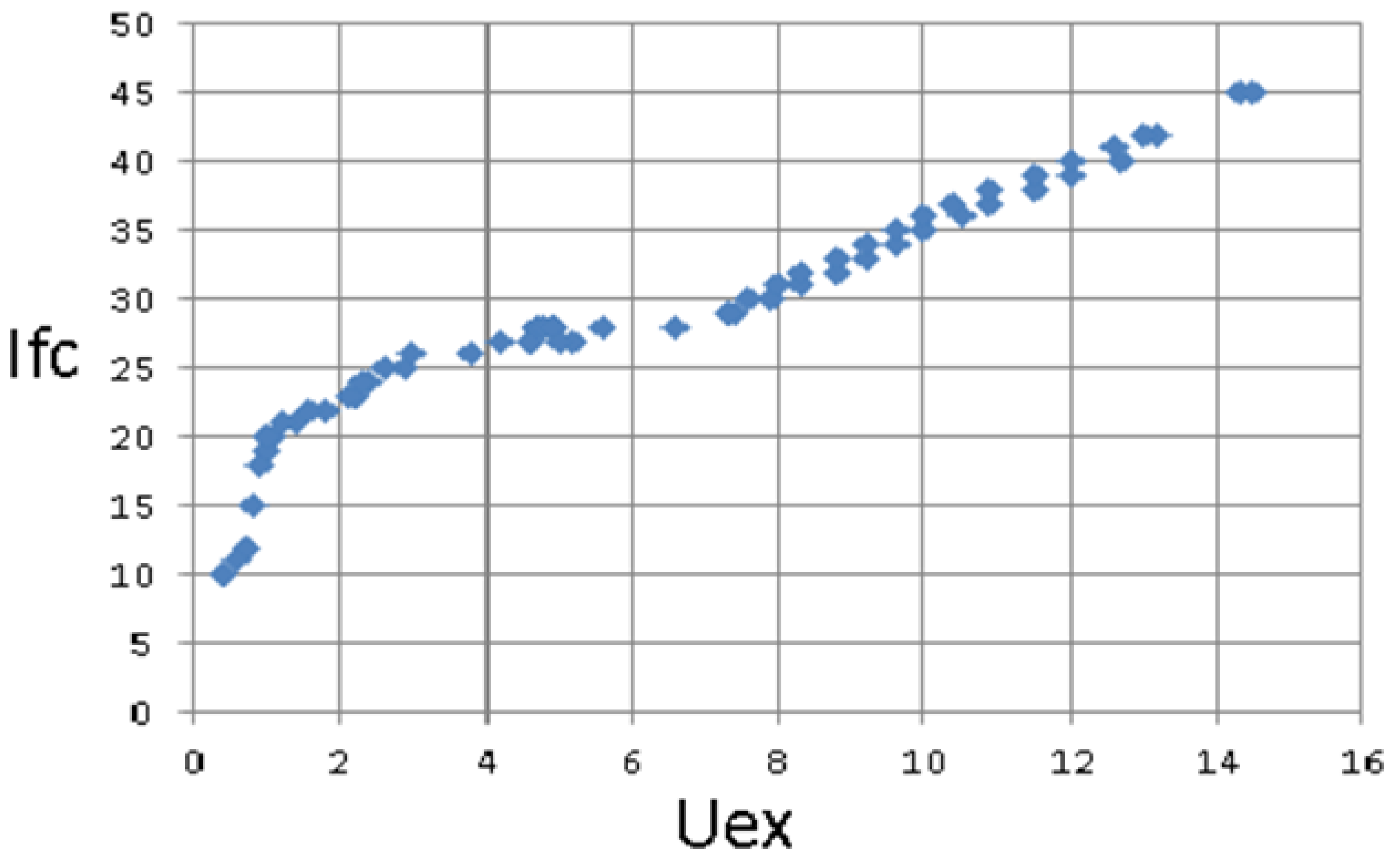
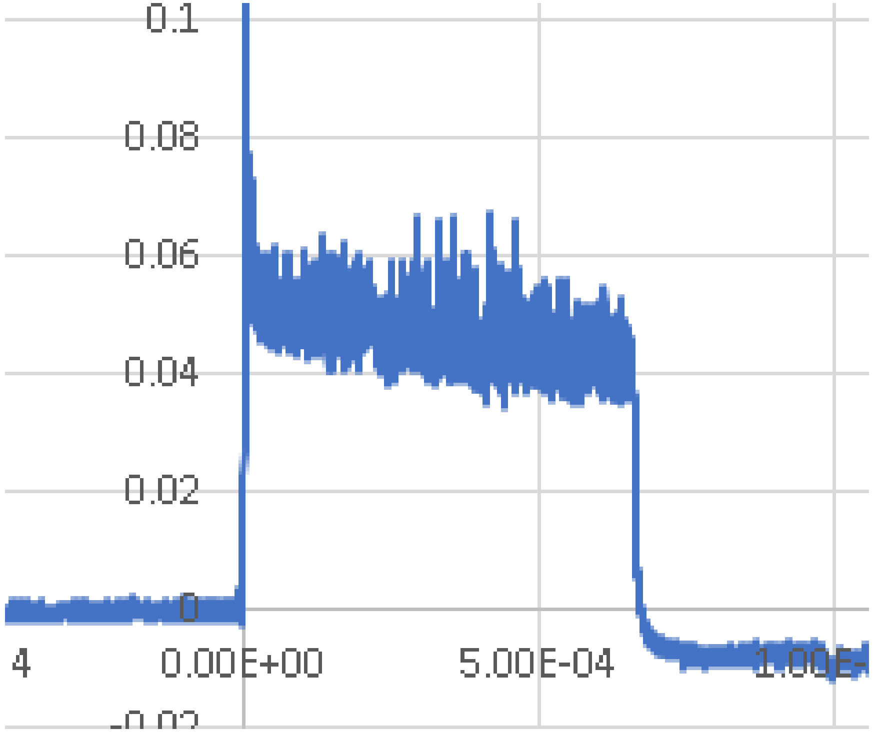


Photo of back side of tantalum collector heated by ion beam observed through a front window(top) and a collector melted by ion beam (bottom)

Dependence of Faraday current (mA) on Extraction voltage (kV). Prf=1.5 kW, Um=3 V.





Signals of positive ion on collector Ic = 50 mA at RF power ~1.5 kW in the plasma. The time scale is 0.5 ms/div.

CW operation of the SA positive ion source with positive ion extraction was tested with RF power up to ~2 kW from the generator (~ 1.5 kW in the plasma) with production up to Ic=50 mA. Long term operation was tested with 1.8 kW from the RF generator (~1.3 kW in the plasma and 0.5 kW is dissipated in the antenna and matching network) with production of Ic=45 mA (Uex=15 kV). This mode of operation was tested during : 30 days. After this test SA ion source was capable to work.

The collector current is increase with increase of a magnetic field up to Um ~8 V. The specific power efficiency of positive ion beam production in CW mode is up to Spe = 200 mA/cm^2 kW.

CW RF discharge can be triggered with CW discharge in the Triggering Plasma Gun (TPG) at gas flow Q~8 sccm and can be supported up to Q~3 sccm. The main CW discharge in SA RF SPS can be triggered without discharge in the TPG at Q~ 10 sccm and supported up to Q~4 sccm.