

Construction of External Antenna RF H-minus Source in CSNS

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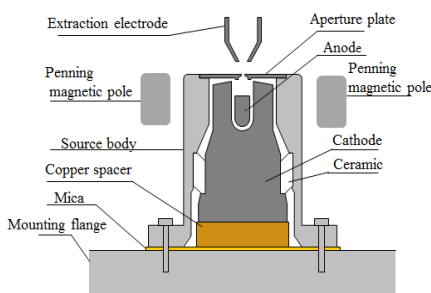
China Spallation Neutron Source

The accelerator complex of China Spallation Neutron Source (CSNS) consists a penning ion source, RFQ-DTL linear accelerator, and a rapid cycling synchrotron (RCS). CSNS project phase-I aims to provide a beam power of 100 kW on a tungsten target, which requires at least 15 mA H^- beam current from the ion source with a repetition rate of 25 Hz and pulse width of 500 μ s. CSNS generated the first neutron beam in August of 2017.



The Commissioning Source

The present Penning surface plasma source has the same structure as the ISIS H^- source. This source can produce more than 50 mA beam current with pulse width of 500 μ s and a repetition rate of 25 Hz. The H^- beam from the Penning source has an emittance around 0.8 π mm-mrad, which is much larger than the acceptance of the RFQ, namely 0.2 π mm-mrad. Consequently, only 15~25 mA ion beam is injected to the RFQ.

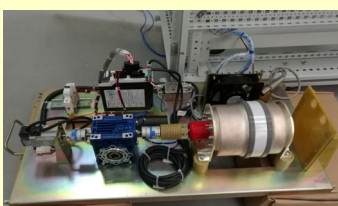
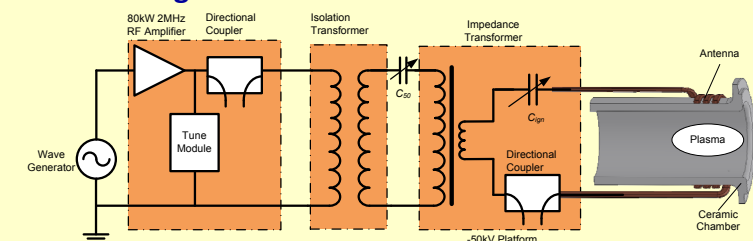


RF Source for CSNS Phase-II

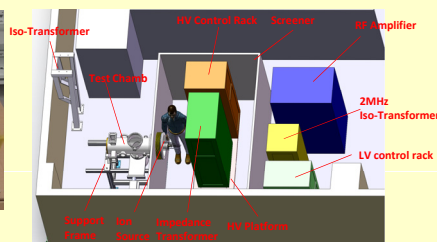
CSNS project Phase-II aims to upgrade the ion beam power to 500 kW, which requires 40 mA H^- beam current from the ion source. The maximum pulse width of the H^- beam should be more than 1000 μ s; and the remittance is required less than 0.25 π mm-mrad

| Project Phase | I | II |
|---------------------------------|----------|----------|
| Beam Power on target [kW] | 100 | 500 |
| Proton energy [GeV] | 1.6 | 1.6 |
| Average beam current [μ A] | 62.5 | 312.5 |
| Pulse repetition rate [Hz] | 25 | 25 |
| Linac energy [MeV] | 80 | 250 |
| Linac type | DTL | +Spoke |
| Linac RF frequency [MHz] | 324 | 324 |
| Macropulse ave current [mA] | 15 | 40 |
| Macropulse duty factor | 1.0 | 1.7 |
| RCS circumference [m] | 228 | 228 |
| RCS harmonic number | 2 | 2 |
| RCS Acceptance [π mm-mrad] | 540 | 540 |
| Target Material | Tungsten | Tungsten |

The matching Circuit of RF Power

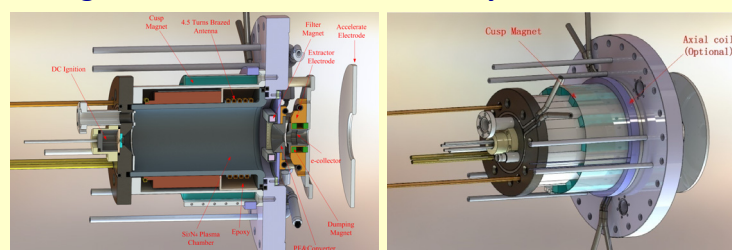


The tunable capacitor is driven by a step motor.

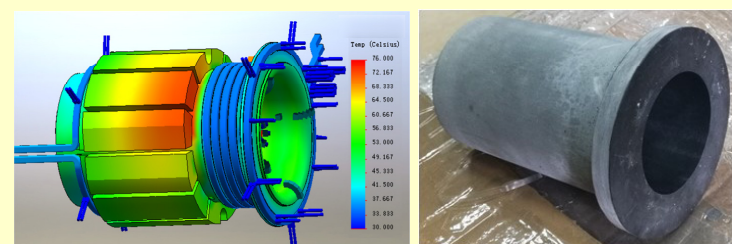


Layout of the test bench.

Configuration of the Ion Source Body



A 4.5-turn antenna is made of copper tube with squared cross-section. The antenna is brazed on a cylindrical plasma chamber which is made of Si₃N₄ ceramic. The plasma chamber has an inner diameter of 67 mm and the thickness of the wall is 5 mm. To increase the high voltage withstand, each turn of the antenna is separated by threaded ceramic teeth. Then the antenna is covered with a PEEK container filled with epoxy.

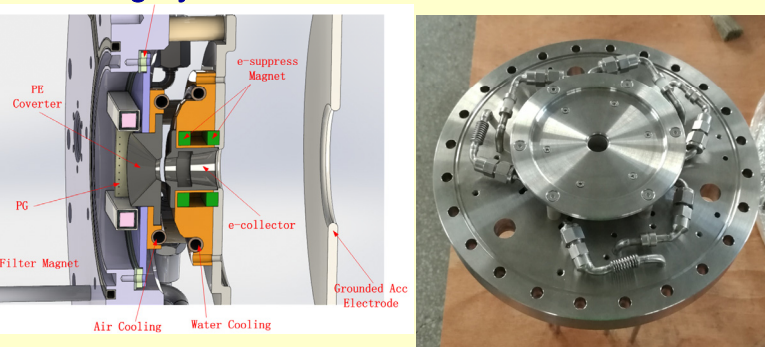


According to the simulation, the maximum temperature of the ceramic is less than 80°C while 1500W average power is applied.

Physical properties of silicon-nitride comparing with Alumina and aluminum-nitride. Silicon-nitride is a compromise of flexural strength and thermal conductivity, but with higher thermal shock resistance.

| | Al ₂ O ₃ | AlN | Si ₃ N ₄ |
|--------------------------------|--------------------------------|--------|--------------------------------|
| Thermal Conductivity (W/mK) | 16~27 | 70~150 | 16~90 (60) |
| Thermal Expansion (ppm/K) | ~7 | ~4.6 | ~2.8 |
| Flexural strength (MPa) | ~350 | ~300 | ~900 |
| Vicker Hardness (GPa) | ~16 | ~11 | ~14 |
| Heat shock resistance (Cesius) | ~200 | ~400 | ~800 |

Extracting System



To minimize the spark rate between the HV electrodes of the extracting system, the surface of the electrodes are coated with one layer of TiZrV material, which has very low secondary electron emission rate.