A.5: Development of a compact external RF antenna based H^- ion source

An RF based pulsed H^- ion source has been developed in-house by ISDDS/PLLD at RRCAT for application in proposed Indian Spallation Neutron Source (ISNS). It has been successfully tested for extraction of 16 mA H^- ion beam current of 2 ms pulse duration at 50 keV and 2 Hz repetition rate. It consists of pulsed RF ignitor, main plasma generator, three-electrode extraction system, extraction chamber, hydrogen gas purging system, RF and DC power supplies, high voltage deck and vacuum system. The experimental prototype test setup is shown in Figure A.5.1. The plasma generating and extraction equipment are mounted on a high voltage deck rated for 80 kV DC. The cut view of CAD schematic is shown in Figure A.5.2(a), and the fabricated prototype hydrogen plasma generator is shown in Figure A.5.2(b). The vacuum and accelerating system were at ground potential. Differential vacuum was created using 3 turbo molecular pumps having 3000 lps capacity connected to 6-port (DN160CF) extraction chamber. During the operation, hydrogen gas was purged at 25 standard cubic centimeter per minute, generating 5.5×10^{-2} mbar gas pressure in plasma chamber and 4.5×10^{-4} mbar in extraction chamber. A low density, low temperature seed plasma was generated using an ignitor based on 13.56 MHz,1 kW pulsed RF source. The developed wide band 1 kW amplifier is shown in Figure A.5.3(a). High density plasma generated using 2 MHz, 60 kW pulsed RF power through external antenna. Pulsed RF power source was developed using SiC MOSFET as shown in Figure A.5.3(b) along with RF transformer and matching network. The RF power was coupled to the main plasma by an external RF antenna through inductive coupled mechanism. Figure A.5.4(a) shows recorded ignitor (Ch-1) and main (Ch-2) RF antenna driving currents. As soon as seed hydrogen plasma was created, ignition antenna current reduced to 30 A from 60 A peak current.

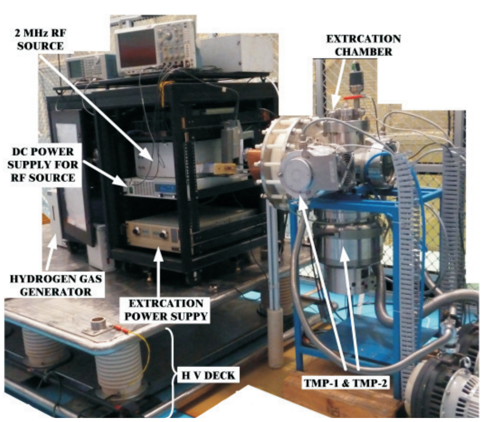
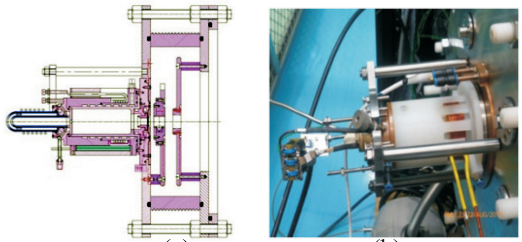
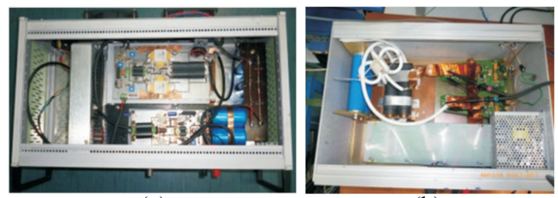


Fig. A.5.1: Experimental setup of RF based H^- ion source.



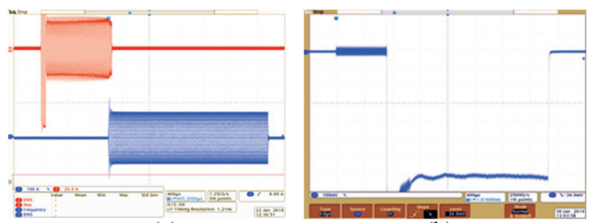
(a) (b)

Fig. A.5.2: (a) CAD-schematics for RF based H^- ion source. (b) Prototype RF based H^- ion source, ignition system and main plasma generator.



(a) (b)

Fig. A.5.3: (a) 13.56 MHz 1 kW RF amplifier for plasma ignitor. (b) 2 MHz pulsed 60 kW RF amplifier for H^- ion source main plasma generator.



(a) (b)

Fig. A.5.4: (a) Ch-1:ignition antenna RF current (20 A/dev.) and Ch-2:main antenna RF current (100 A/dev.); time scale 0.4 ms/dev, and, (b) extracted H^- ion beam current ~16 mA at 50 kV DC with 2 ms pulse duration.

Just before ignition current pulse ends, the main 2 MHz RF source starts delivering power to the plasma. H^- ion extracted using three electrodes (plasma electrode, extraction electrode and ground electrode) extraction geometry as shown in Figure A.5.2(a). The co-extracted electrons from plasma electrode with ~12 keV energy were steered and dumped in the extraction electrode by keeping permanent magnet dipoles in side extraction electrode. Heavy H^- ions have very little effect of these dipoles and travel straight towards ground electrode. The extracted H^- ion beam current is measured using Faraday cup. Figure A.5.4(b) shows the extracted H^- ion beam of 16 mA at 50 kVDC accelerating voltage with 2 ms pulse width and 2 Hz repetition rate. This RF based H^- ion source will be used for the 1 GeV H^- linac of the proposed ISNS.

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