Development of deuterium-deuterium compact neutron source

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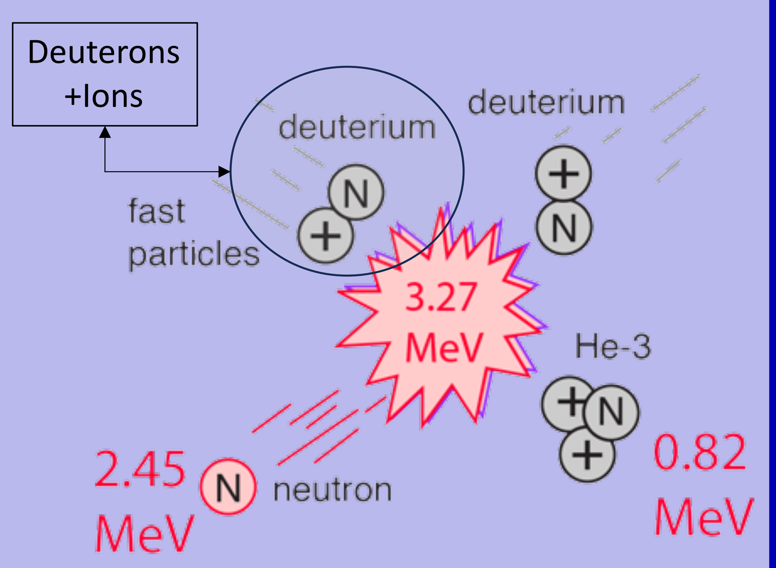
Introduction

In the present work, we will present the status of the **deuterium-deuterium (D-D) neutron source** that is being developed in collaboration between the University of Granada and the University of the Basque Country (Spain). Our neutron source consists of an **ECR ion source**, which accelerates a **deuteron beam** towards a **deuterated target**. The deuterium plasma ionization is achieved by radiating the cylindrical ECR plasma chamber with a 2.45 GHz **magnetron** signal and an 875 G **permanent magnetic field**.

Once the plasma is generated, the deuterons are **accelerated** towards a copper target disk with a deuterated titanium mesh fixed to **-100 kV,** which generates the desired neutron radiation.

D-D Fundamentals

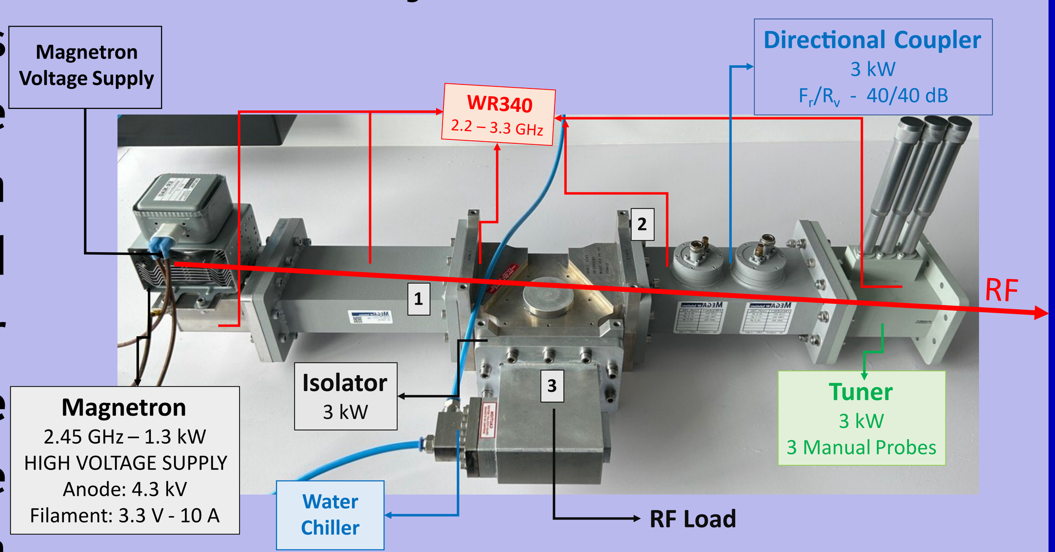
The D-D fusion reaction is described as **^{2}H(d,n)^{3}He**. By colliding deuterium positive ions, known as **deuterons**, against other deuterium particles, a 3.27 MeV **fusion reaction** is generated, where **2.45 MeV** corresponds to a neutron.



RF System

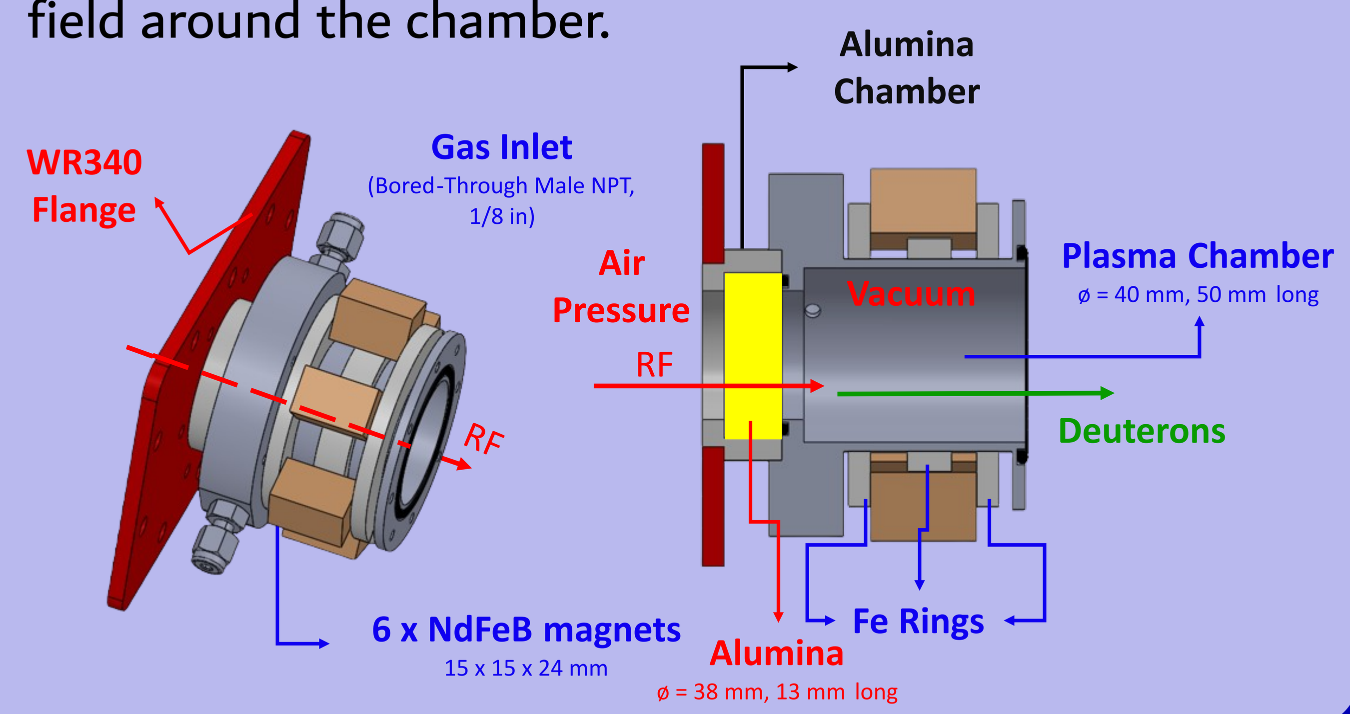
An RF signal is needed to **ionize** the deuterium inside the plasma chamber. This RF signal is generated using a **high-power magnetron** able to achieve **1.3 kW** of power with a frequency of **2.45 GHz**. The RF wave is transmitted towards the plasma chamber by a WR340 chain.

Inside this chain, a 3 kW watercooled **isolator** has been implemented to avoid damaging the magnetron with the reflected power coming from the plasma chamber. Moreover, two **directional couplers** monitor both forward and reflected power to the plasma chamber. Finally, a **3 manual probe tuner** is used to modify the impedance of the WR340 system to tackle the impedance mismatch as the plasma is ignited.



Plasma Chamber

An **ECR plasma** is ignited from deuterium by ionizing it with a 2.45 GHz RF signal and fixing a magnetic field around the chamber.

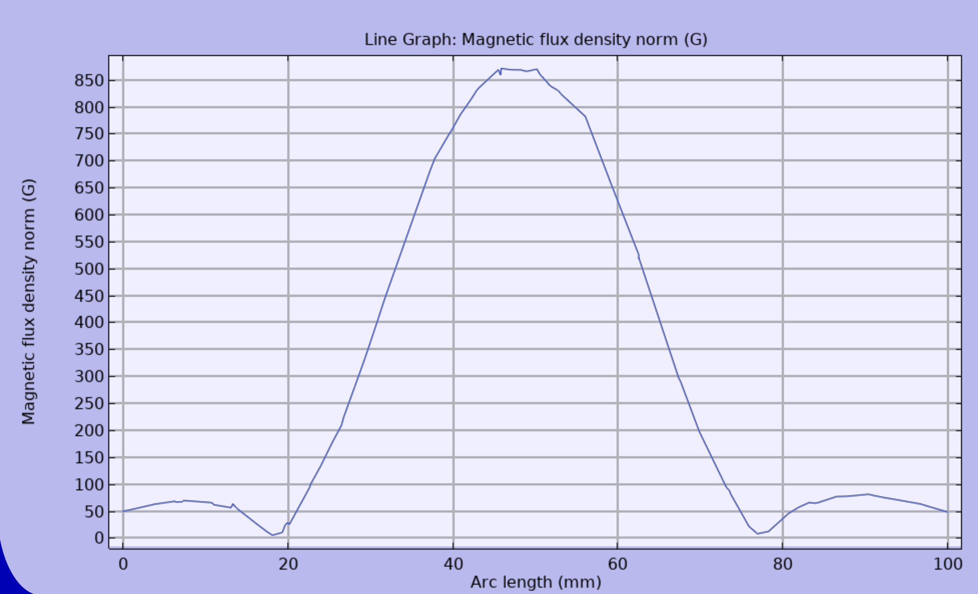


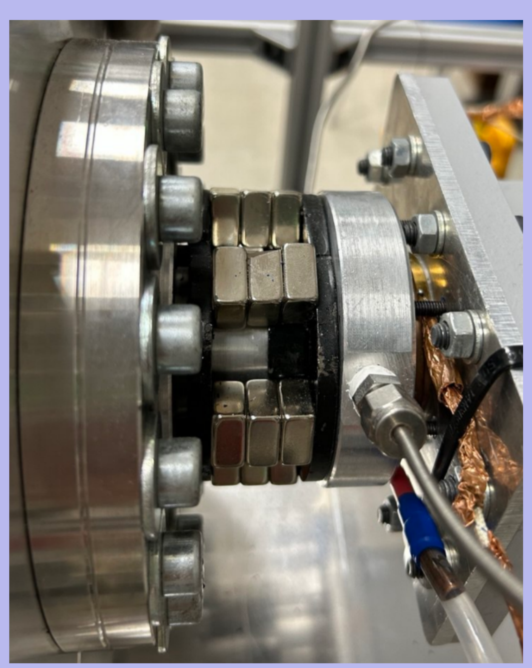
Magnetic simulation

A magnetic field needs to be induced inside the plasma chamber for an ECR plasma to ignite. In our case, for a 2.45 GHz signal the magnetic field needed is of **875 G**, following Eq. 1. For this purpose, 6 **NdFeB** magnets with a dimension of 15 x 15 x 24 mm

$$f = \frac{q \cdot B}{2\pi \cdot m_e} (\text{Hz})$$

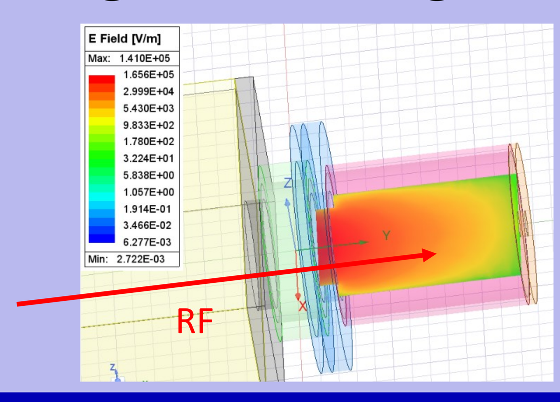
Eq. 1.



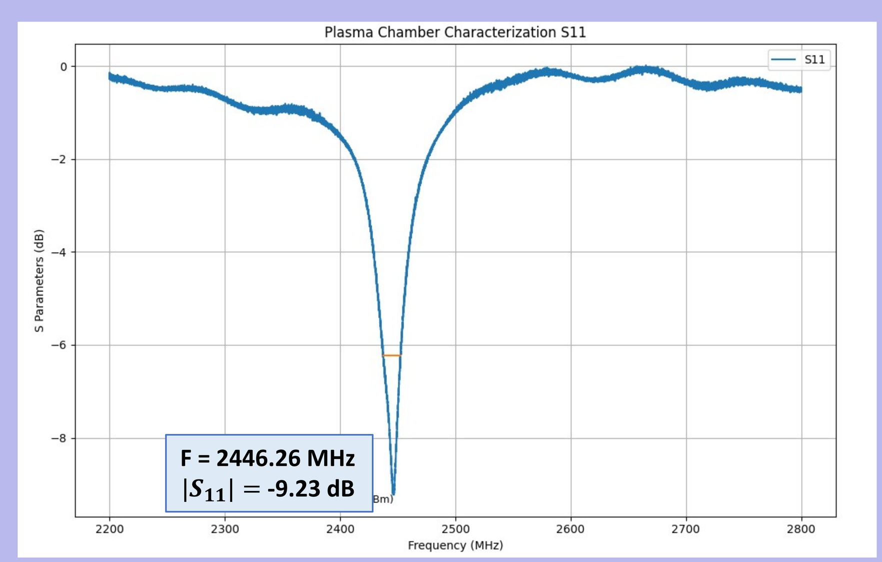


EM Simulation

As the plasma chamber has a cylindrical shape, an iris has been designed to adapt the impedance between the chamber and the WR340 chain. In order to achieve this impedance adaptation, two 30 mm diameter and 5 mm long irises have been designed, which added to the 38 mm diameter and 13 mm long **alumina disk** in the middle of both irises, and the plasma chamber can adapt the RF signal coming from the magnetron.

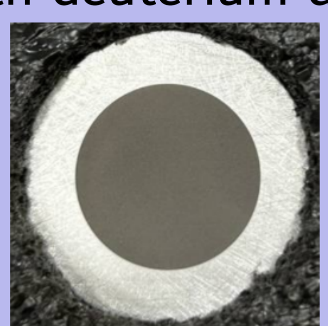


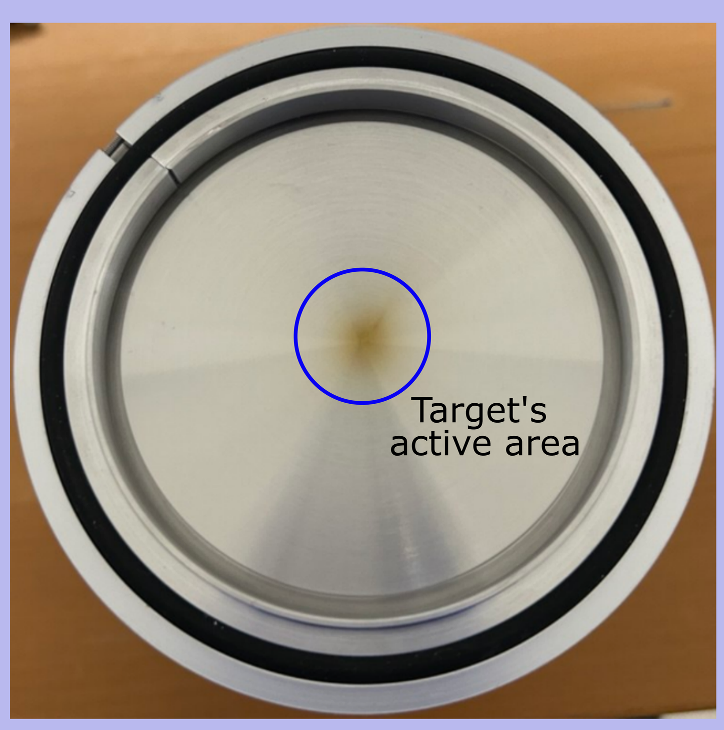
The RF characterization results for the whole plasma chamber geometry suggest the designed work as expected having S_{11} = −9.23 dB at a frequency of 2.446 GHz.



Extraction & Target

For the moment, **no electrostatic lenses** have been added to the extraction part, as the current just with the plasma electrode and negative potential fixed to the target wants to be measured first. The first measurements gave a beam current of around **40 uA** with hydrogen plasma and target at **-30 kV**. Lenses will be needed to optimize the beam focusing towards the target's active area. The target the deuteron beam will be accelerated towards consists of a metallic coin that has a titanium mesh with deuterium deposited in one of its faces.





Current State

The ion source is fully operational. Until the bunker is available, for radioprotection reasons, deuterons cannot be accelerated, so there is no neutron radiation.

Currently, the first ion beam current measurements are underway using hydrogen, and other gasses will be soon tested.