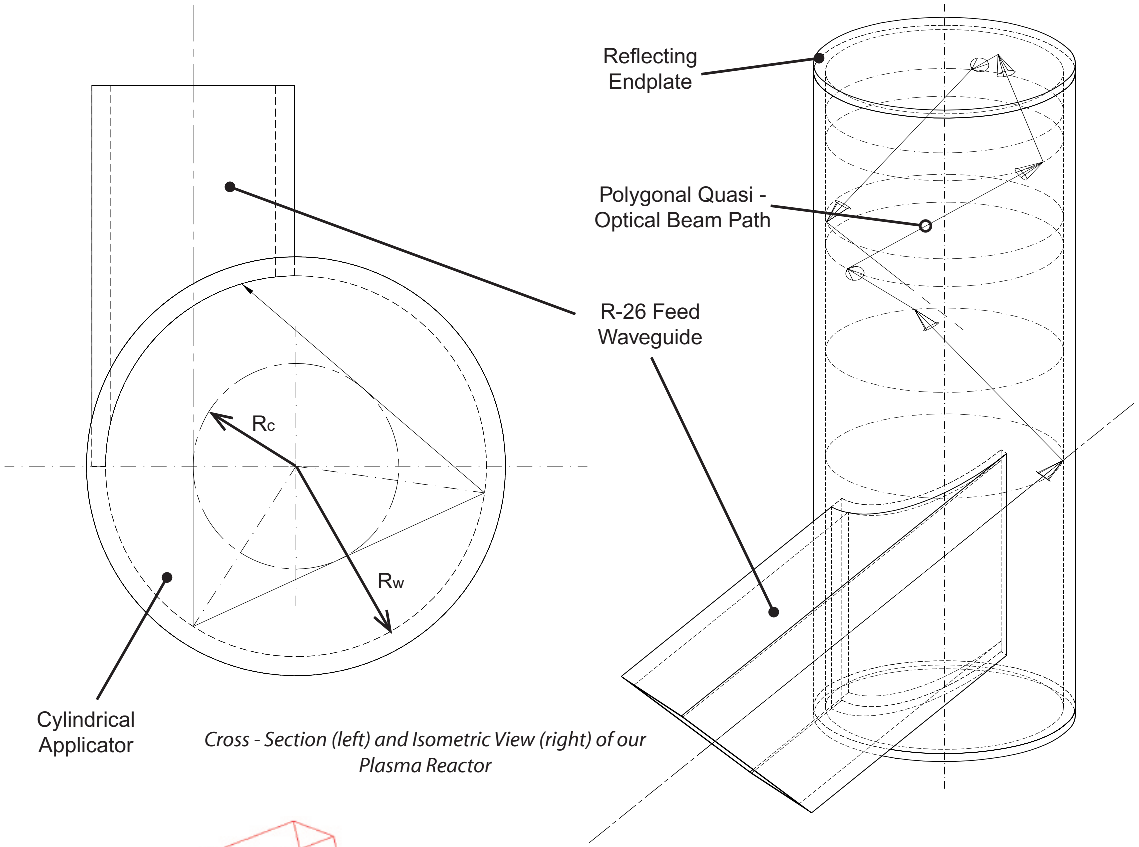
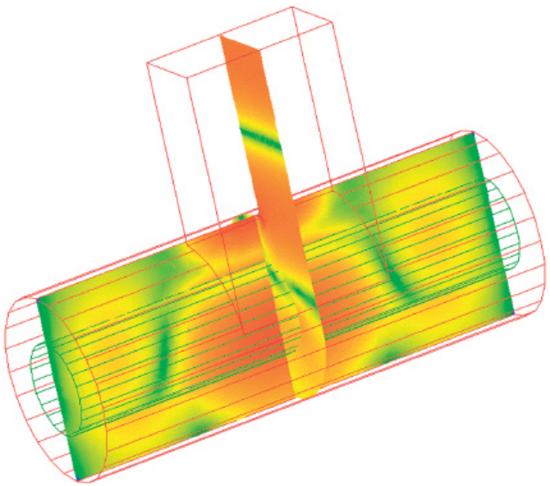
Load • Calorimeter • Plasma Reactor

Load, Calorimeter and Plasma Reactor



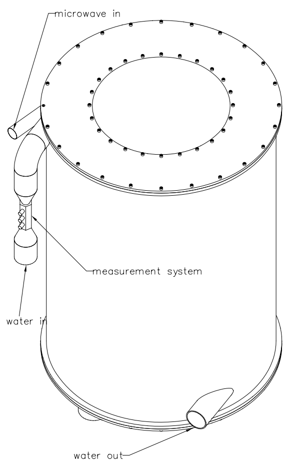
Cross - Section (left) and Isometric View (right) of our Plasma Reactor



HF - Field Simulation of Plasma Reactor

A High - Power HF load which uses the functional principle of our plasma reactor for minimizing the back reflected HF -power.

To apply the load as a calorimeter, the mass flow, pressure and temperature rise of the cooling fluid is observed. This allows the calculation of the absorbed microwave power.



Loads and calorimeters are used to absorb microwaves by converting them into heat where calorimeters additionally have provisions to evaluate the amount of the absorbed microwave power by means of measuring the generated heat. An ideal load would not allow any reflection back into the feed waveguide but would totally absorb the injected power. For real loads the reflected power has to be kept at least below 20 dB.

In monomode waveguides a common method to achieve high absorption is to have the a partially absorbing, transmitting and reflecting obstacle like a thin layer or a water hose in a defined distance from a totally reflecting wall. The phase difference between the wave reflected at the obstacle and the wave reflected at the wall is as such that both reflected waves cancel each other. Then all the power is absorbed in the obstacle, hence we have a perfect load.

While this principle is appropriate for moderate power levels it fails as the power goes up - since the obstacle is too small for taking the generated heat - or as the frequency goes up - since the phasing space is reduced and the obstacle is no longer small compared to the wavelength.

These requirements have lead to a novel design. The calorimeter consists of a cylindrical tank, where the microwaves are absorbed at the wall. As described in [1] a feed waveguide is attached to the tank such that the launched power couples efficiently into rotating Eigenmodes of the cylindrical tank. As the Eigenmodes propagate on helical paths (or polygonal lines) down the tank they are attenuated during each reflection on its walls. As the remaining fraction of the power reaches the end of the cylinder the microwave power is axially reflected however their direction of rotation remains unchanged. As it reaches the position of the feed waveguide due to the sense of

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rotation the coupling to the feed waveguide modes is low. Hence the power is trapped in the tank the power and reflected from the load is low.

To achieve a constant absolute absorption along the axis of the tank the absorption coefficient of its inner surface has to increase in axial direction at roughly the same ratio the remaining microwave power decreases. This can be achieved by covering the inner surface of the cylinder with materials of different conductivity. For extremely high power levels this can be copper or alumina, for lower power levels this will be stainless steel and for even lower levels this can be a TiO_2 sprayed surface. The absorption can also be increased by gently reducing the radius of the cylindrical tank.

To remove the generated heat the cylindrical tank is provided with cooling installations. To use such a load as a calorimeter the absorbed power is evaluated by monitoring the temperature, pressure and flow rate of the cooling liquid.

The tremendous features of these type loads gave rise for applying the principle of rotating modes for the design of plasma chemistry reactors. Again the feed waveguide is attached to the cylindrical tank such that a rotating mode inside the tank is achieved. Different from the load the walls are kept conducting. Thus inside the tank even at moderate levels of the feed power a resonant high field amplitude can be achieved.

Along the cylinder axis a glass pipe can now be placed that carries reactant gases at a given pressure. Due to the high field amplitude inside the cylinder electrical break through conditions for igniting and maintaining a plasma are more reliably achieved than in conventional reactors.

Most important is that there is no considerable change in impedance during ignition and burning of the plasma. This allows chemically more stable reactions. Additionally many plasma reactors suffer the problem that the dielectric behaviour rapidly changes during the ignition. This arrangement has the advantage that the field amplitude in the reactor only weakly depends on the plasma parameters.

The first plasma reactor based on this principle for the design frequency of 2.45 GHz and a non oversized standard R-26 feed waveguide has been designed at our partner company IMT and built and tested at IMF I at the Research Laboratory of Karlsruhe (FZK) [2][3]. The design modes of the reactor have been the rotating modes TE111 through TE114 at a reasonably low dielectric constant of the plasma. This behaviour had been experimentally confirmed.

As the dielectric constant of the plasma increased the plasma applicator mode jumped to TM01n, however even during these jumps the plasma remained burning. While in conventional reactors the plasma ignites in a pressure range between 1 to 5 mbar and extinguishes at 30 mbar the range of stable ignition has been broadened to 1 through 50 mbar and the plasma remains burning up to 100 mbar.

Cross section, side view and an isometric view can be seen in figures on the front side.

The axis of the feed waveguide is transverse offset with the axis of the cylinder such that it coincides with the radius of the caustic, Rc, representing the applicator mode. More about how to calculate the caustic for a given cylinder radius Rw and mode can be found in [1].

Reference List

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