

Experimental Plasma Physics

Codrina Ionita-Schrittwieser
Florin Enescu
Roman Schrittwieser

Innsbruck Experimental Plasma Physics Group
IEPPG

Institute for Ion Physics and Applied Physics
University of Innsbruck, Austria

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What is plasma?

Plasma is the so-called fourth state of matter:

It is the state of matter most abundant in the universe
(more than 99% of the visible matter of the universe are in the plasma state).

- **Any substance that is heated to more than a few thousand degrees will become plasma.**
 - Depending on its temperature, its molecules can be excited and/or ionized as such, or will be dissociated and then excited and/or ionized.
 - If the material consists of atoms these will directly be excited and/or ionized.
- **Eventually a plasma will consist of positive ions, free electrons, neutrals, photons and possibly also of negative ions.**
- **There are many types of plasmas, distinguished by their composition, density n , temperature T , and other parameters such as the plasma potential Φ_{pl} .**
- **Plasmas are usually quasi-neutral, i.e. per volume unit there are almost equal numbers $n_{+,-}$ of positive and negative charges $q_{+,-}$ so that: $|\sum q_+ n_+ - \sum q_- n_-| \ll \sum q_+ n_+$**
- **Any stronger deviation from quasi-neutrality leads to the creation of strong electric fields which try to re-establish quasi-neutrality – unless there is an external constraint.**

Plasma in Nature, Laboratory and Applications

- ***Plasma technology:*** Coating, etching, surface activation, plasma thrusters, welders and cutters, intensive light sources, plasma reactors for plasma chemistry processing and many more.
- ***Medical applications of plasma:*** Decontamination and sterilisation of medical devices and tissue, treatment of biomaterials to enhance their biocompatibility, plasma treatment of wounds and scars, and many more.
- ***Fusion research:*** For solving the future energy problems on the long run, nuclear fusion is the only realistic perspective. The most promising fusion confinement method is the tokamak*).
- ***Terrestrial plasma:*** Lightnings, St. Elmo's fires, upper-atmospheric lightning: blue jets, sprites and elves
- ***Space plasma:*** All active stars as well as almost the entire visible interplanetary, interstellar and intergalactical matter is in the plasma state, including the magnetosphere and the ionosphere of the earth (e.g. auroras).

We do research on:

- Plasma diagnostics with probes and spectroscopic methods,
- Basic plasma physics phenomena,
- Technical applications of plasmas,
- Fusion plasma physics

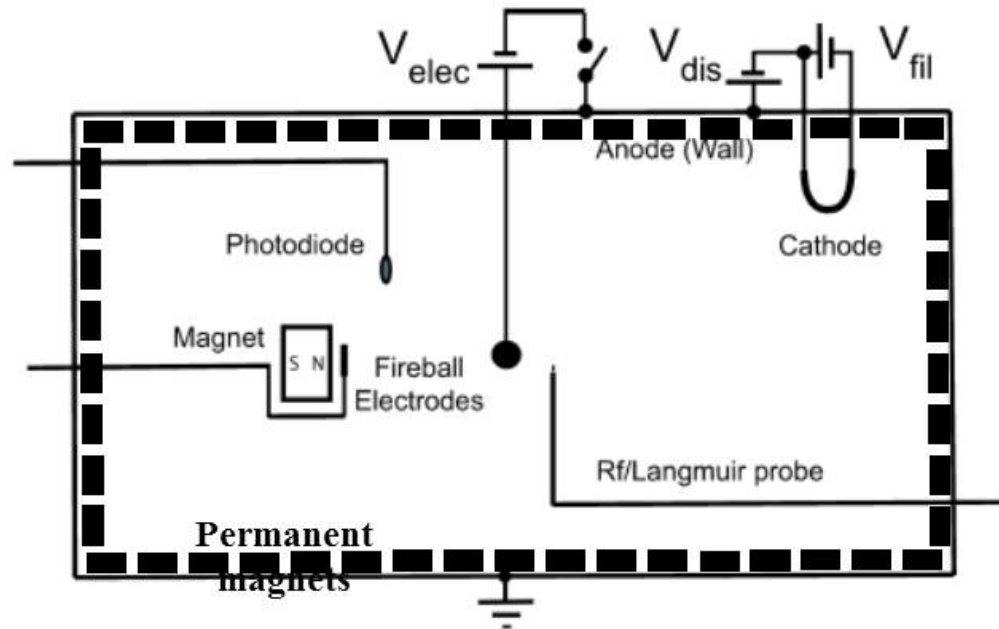
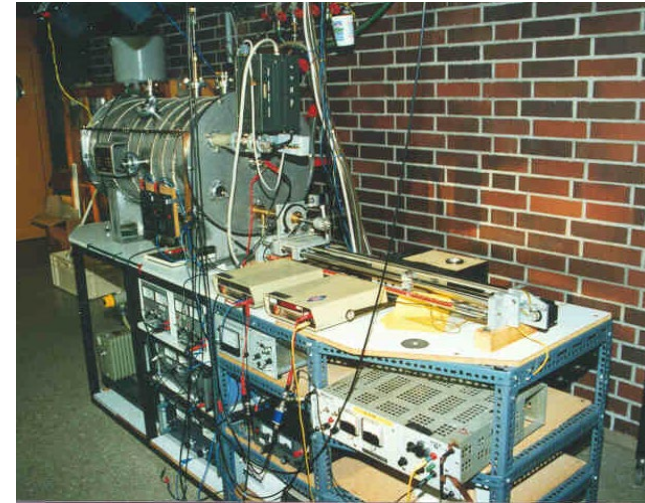
In particular:

- Development of plasma probes (emissive probes, resilient probes, armoured with Ultra-Nano Crystalline Diamond [UNCD]);
- Plasma spectroscopy;
- Localized plasma structures in various plasmas;
- Surface treatment by hollow cathode and dielectric barrier discharges (DBD).
- Transport phenomena in toroidal fusion plasma experiments (tokamaks and stellarators).

Double Plasma Machine (DP-Machine)



Inserting an additional positively or negatively biased electrode into a thin background plasma with sufficiently high background gas pressure will frequently lead to the creation of so-called Fireballs (luminous space charge structures):

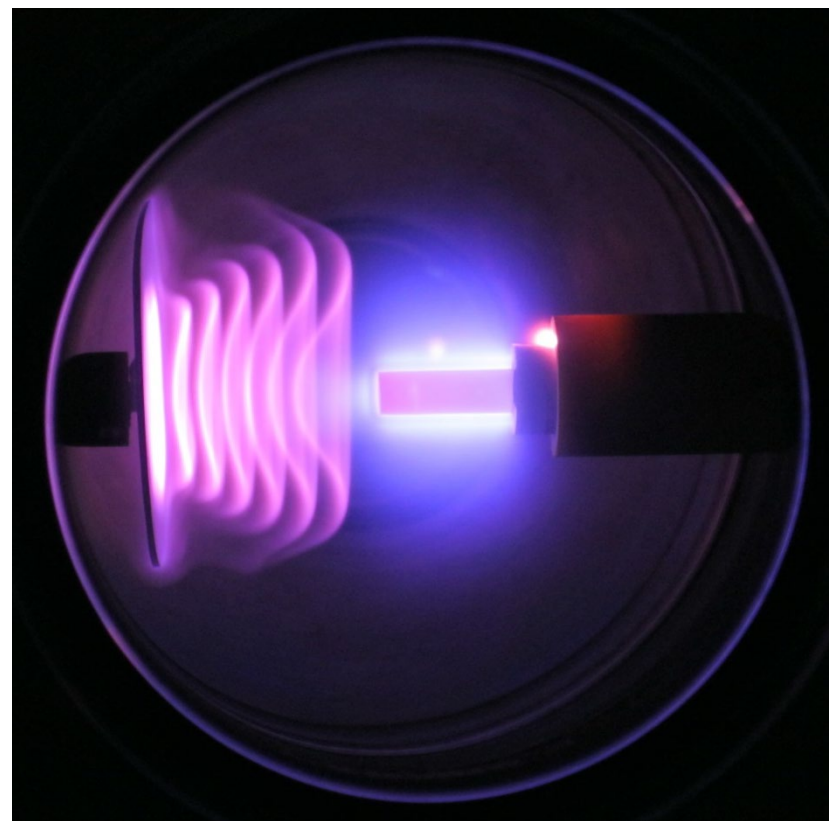
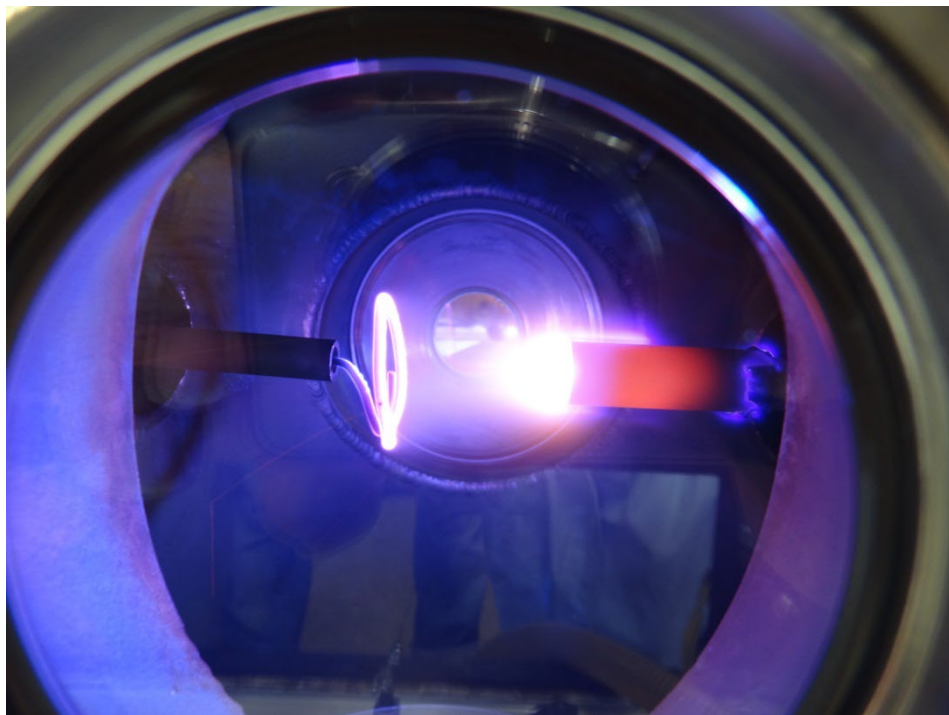


$$n_{pl} \cong 10^{15}-10^{16} \text{ m}^{-3} \text{ and } p \cong 0,5 \text{ Pa}$$

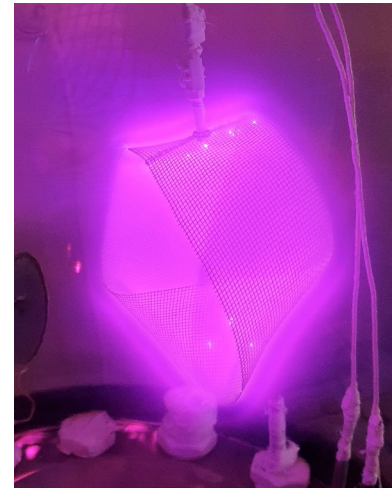
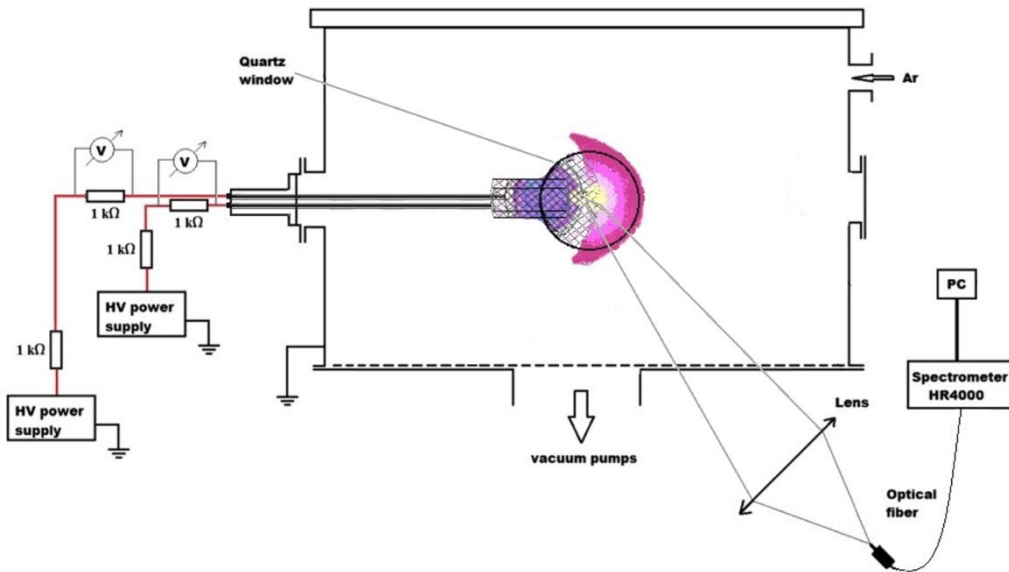


Such phenomena have, by the way, also been observed on space shuttles upon re-entry.

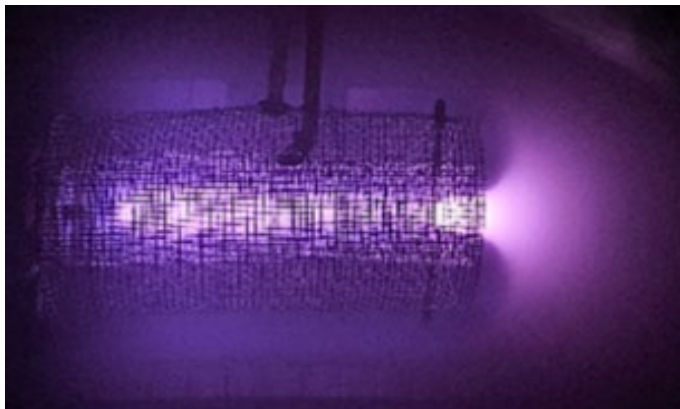
Space Charge Structures



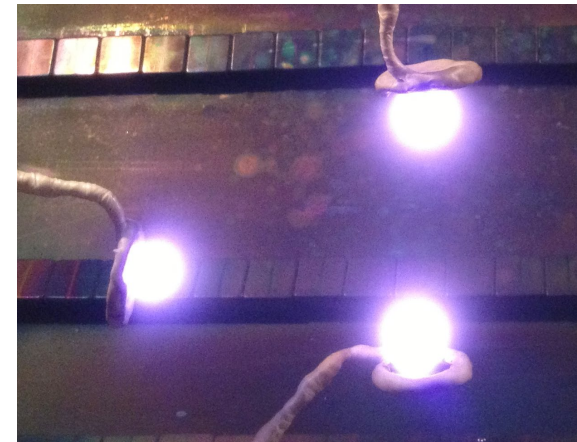
Space Charge Structures Optical investigations



Discharge
on a
gridded
Moebius
band



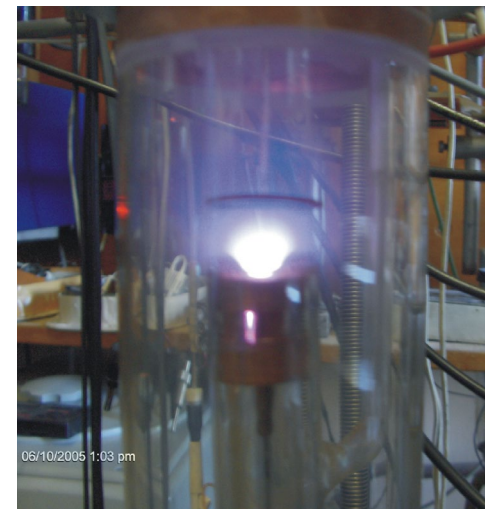
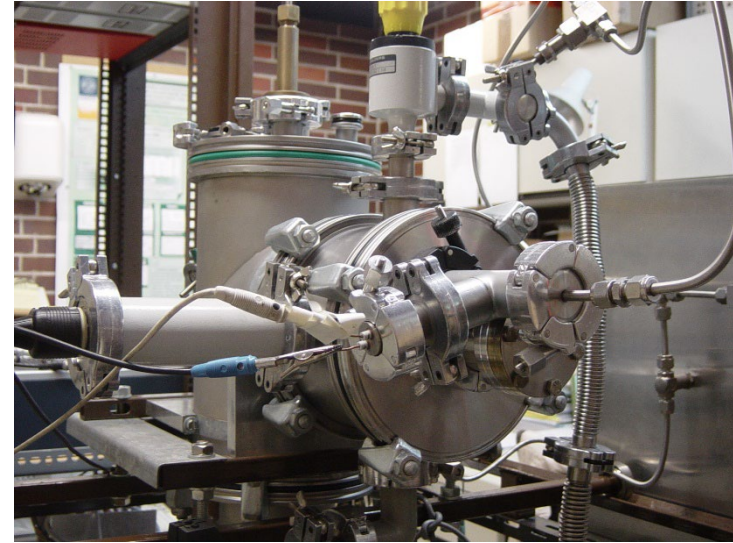
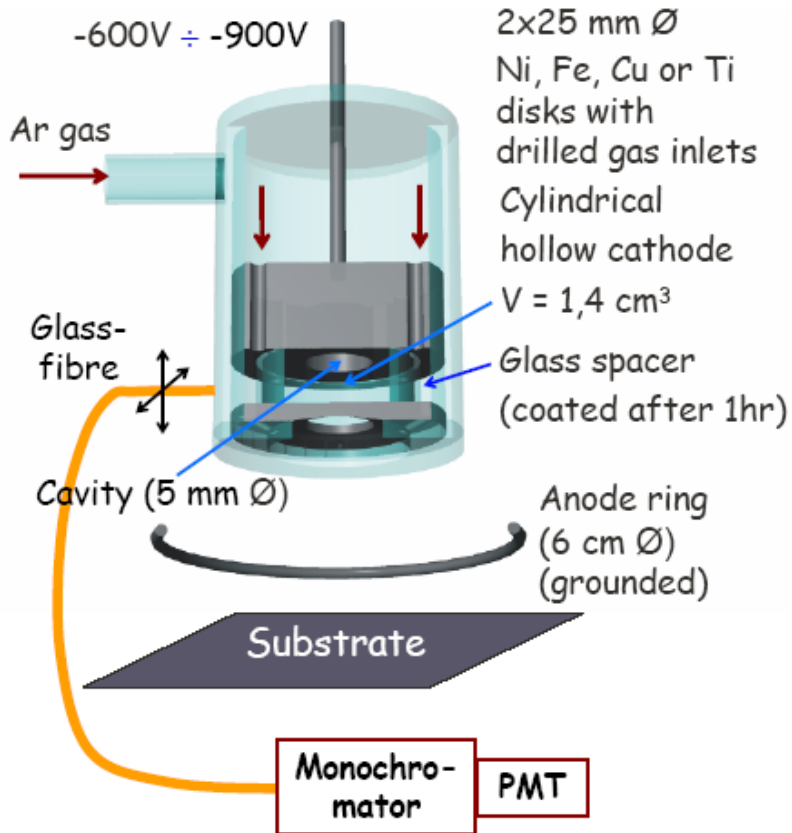
Discharge in a concentric double
cylindrical grid

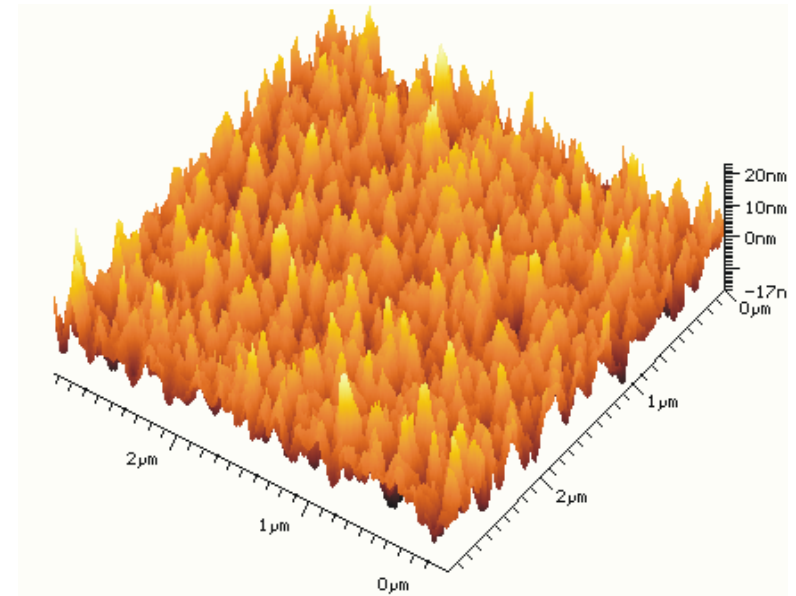
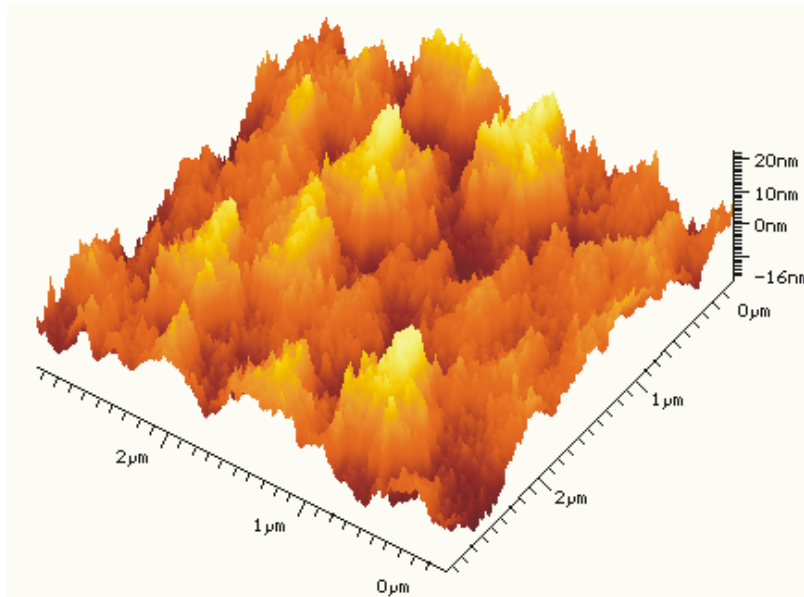


Interaction between three "fireballs"

Hollow cathode

The Innsbruck hollow cathode for coating of various surfaces with various materials





Pictures of a $3 \times 3 \mu\text{m}^2$ large glass substrate coated by nickel in the Innsbruck hollow cathode, recorded by an atomic force microscope.

Left: Coating in 1 cm distance from the hollow cathode.

Right: 2 cm distance.

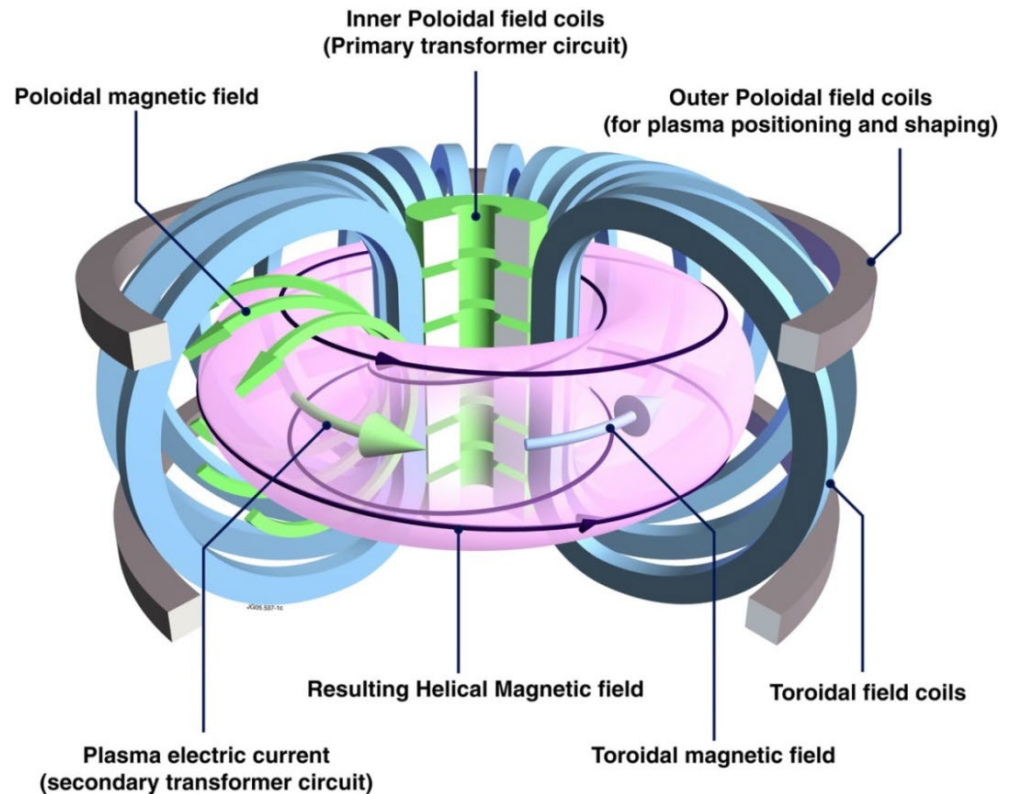
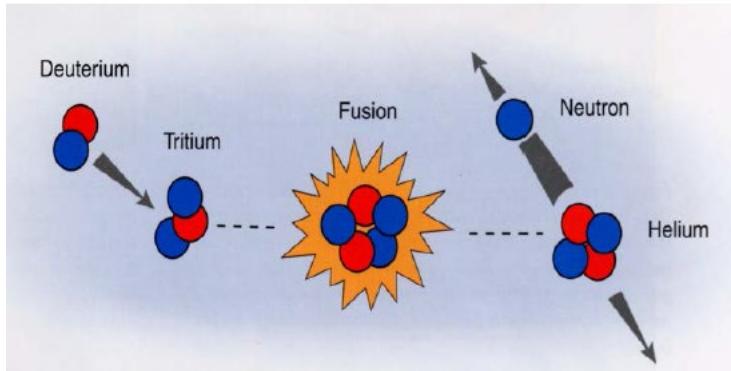
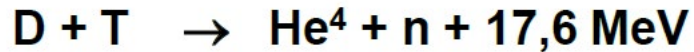
We clearly see that the coating becomes more regular and the grain size decreases for larger distance, i.e., the film becomes smoother.

Probe Development for Toroidal Fusion Experiment



Principle of fusion and of a tokamak:

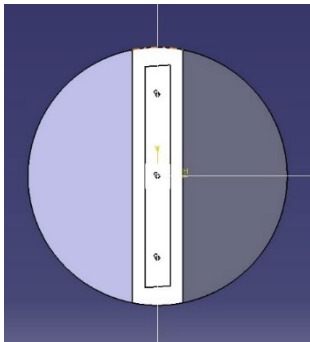
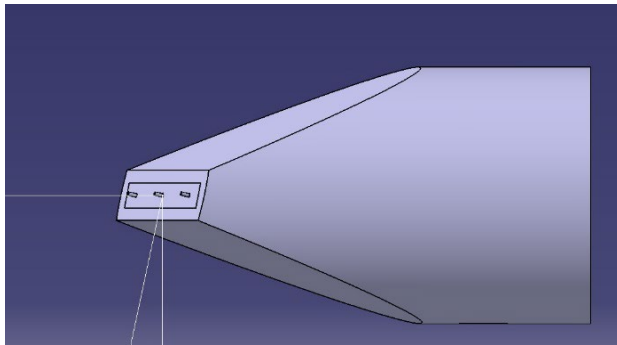
The fusion process with lowest threshold:



Probe Development for Toroidal Fusion Experiment

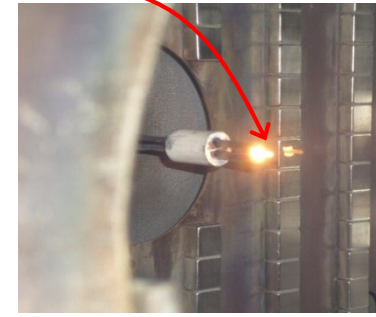
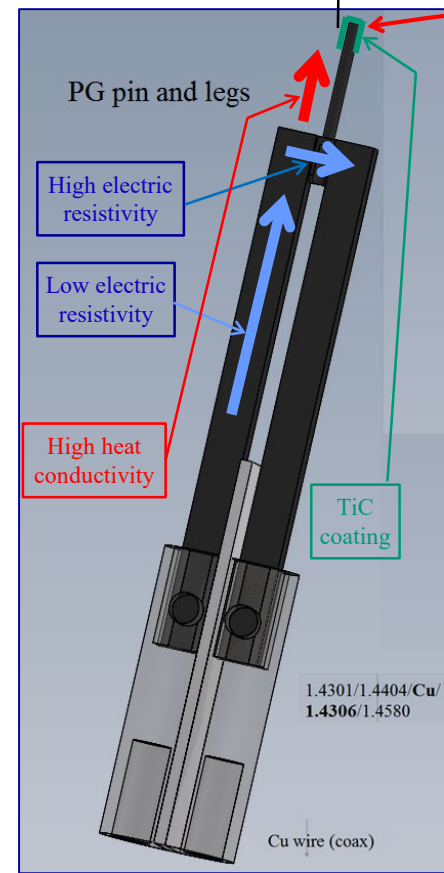


Indirectly heated Electron-Emissive Probe from HOPG (Highly Oriented Pyrolytic Graphite):



**Plasma probe for the
Wendelstein 7-X stellarator
(Max-Planck-Institute for
Plasma Physics (Greifswald,
Mecklenburg-Vorpommern);**
With one indirectly heated
Electron-Emissive Probe (in
the centre)

The protruding part of the pin will
be coated by TiC after assembly.



**Test of the EEP in
the Innsbruck
plasma chamber
(cold Ar-plasma):**
The (here uncoated)
probe pin is heated to
emission by heat
conduction.

Bachelor-Themen bei der ICPPG



1. Untersuchung von Raumladungsstrukturen

(eigene Messungen im Innsbrucker Plasmaphysiklabor mit Sonden und Spektroskopie, unter Anleitung).

2. Medizinische Anwendungen von Plasmen

3. Landwirtschaftliche Anwendungen von Plasmen

4. Plasmatriebwerke

5. Fusion als saubere Energiequelle für die Zukunft

6. Magnetischer Einschluss von Fusionsplasmen

7. "Kalte Fusion", Dichtung und Wahrheit

(welche Methoden sind wenigstens physikalisch nicht unsinnig, welche beruhen zumindest auf einem interessanten physikalischen Effekt, welche sind Unsinn? (myonenkatalysierte Fusion, Bläschen-, „Fusion“).

Buch für 4, und 5.: Francis F. Chen, "An Indispensable Truth, How Fusion Power Can Save the Planet", Springer-Verlag, 2011, XVII, 433 p,

<http://www.springer.com/physics/particle+and+nuclear+physics/book/978-1-4419-7819-6>.