INOPRO

Innovation - Optimization - Process

3D Modeling of Microwave Plasma using Füner Model

Summary

INOPRO

Objectives

Models

Methodology

Geometry

Results

Conclusions

- Created in October 2000
- Consulting for process or product simulation
- 11 engineers / turnover 850k€
- Markets : Microelectronics, Chemistry, nuclear industry...

- CFD
- Thermics (solids, liquids, gaseous)
- Transport phenomena, reactivity
- Electromagnetism - plasma
- Mechanics

- Networking with other consulting experts or researchers

Simulation objectives

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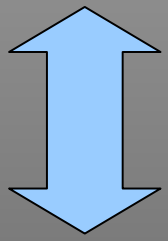
- Industrial equipment design and optimization
- Physical processus explanation



- **Use of simplified model**
- **Model assumptions validation**
- **Models parameters**

Microwave plasma of nitrogen

Models and assumptions

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- Neutral mass, momentum, and thermal conservations (« ns » and « htgh » COMSOL modes)
- Electromagnetism : « rwf » COMSOL mode for 2,45GHz propagation,
- Electron density : $\nabla(-D_e \nabla n_e) = \gamma . (E - E_M) + n_{emin}$

(Insteed of derive diffusuion)

- Permitivity and conductivity depend on :
  - Electron density
  - Electron/neutral colision frequency
- Nitogen plasma, 10 Torr

Methodology

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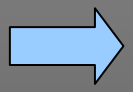
- Em, nmin, gamma are not known
- Collision frequency isn't well known



- First DOE on all parameters

→ no sensibility to em and nmin

- Second DOE, surface of response on gamma and ν_e

→ best fitting for four working points

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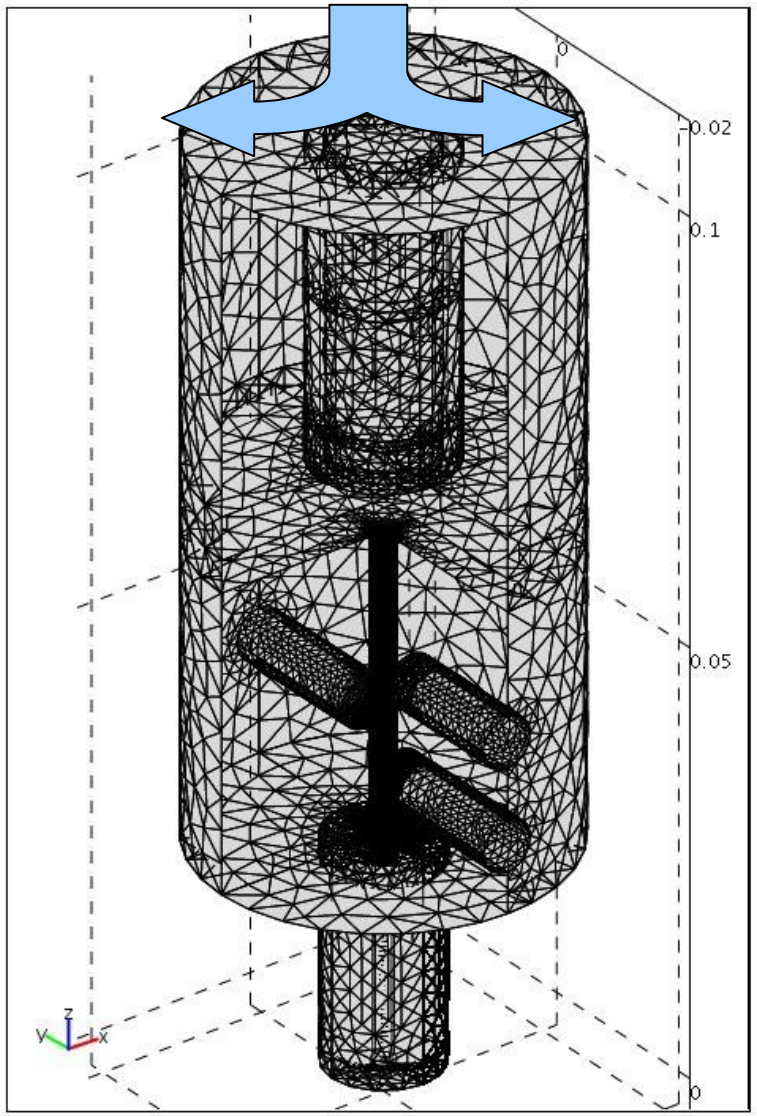

Gas flow

Plasma zone

Accomodation zone

Antenna

Temperature

Results examples

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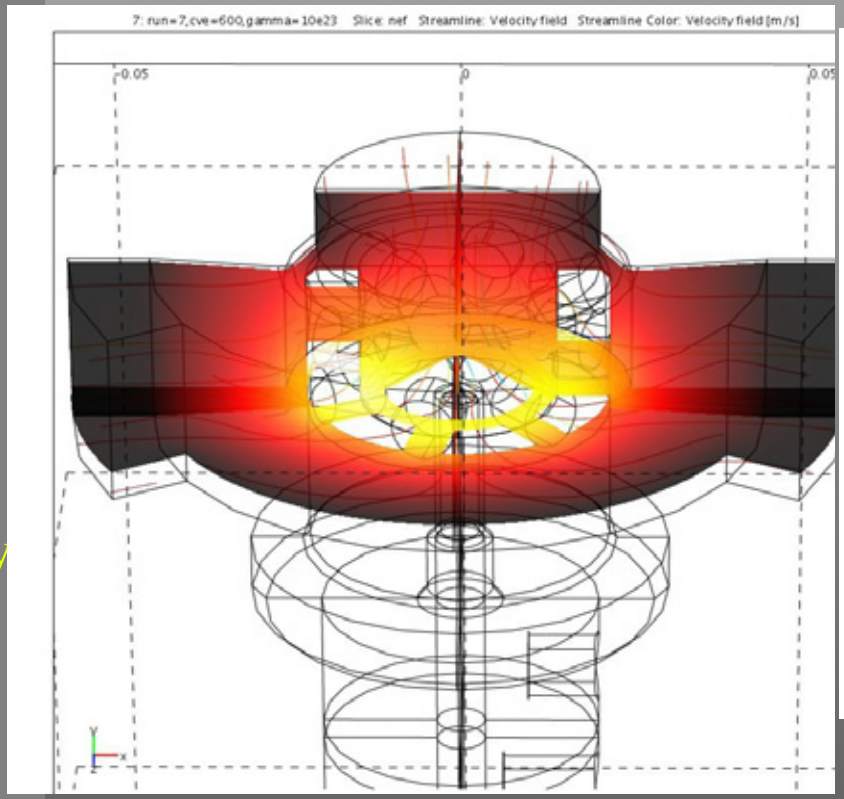
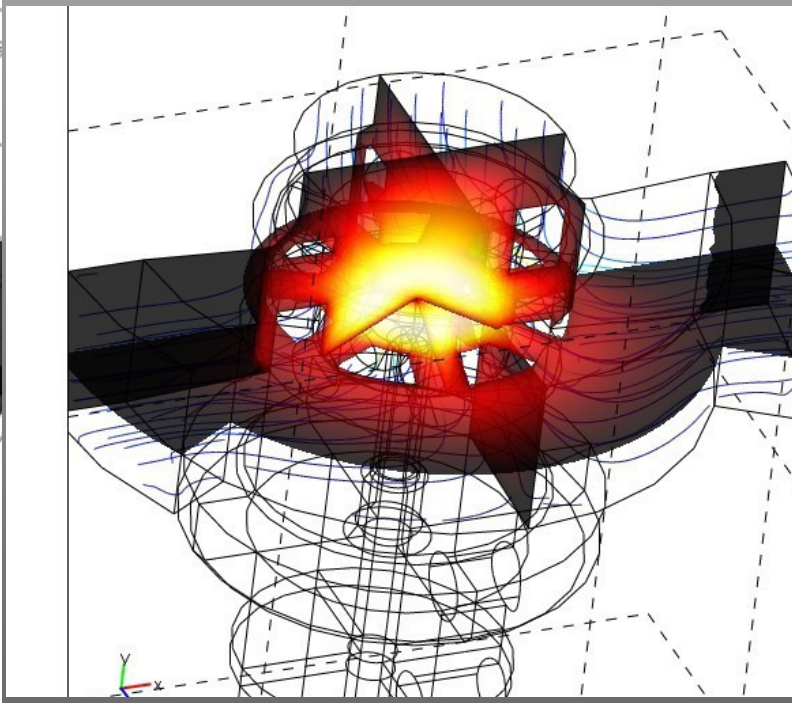
Electron density (max 6.28 10^{18} m^{-3})



Neutral temperature (max 2130K)



We can « see » plasma zone

Do qualitative comparison with experiments

Results examples

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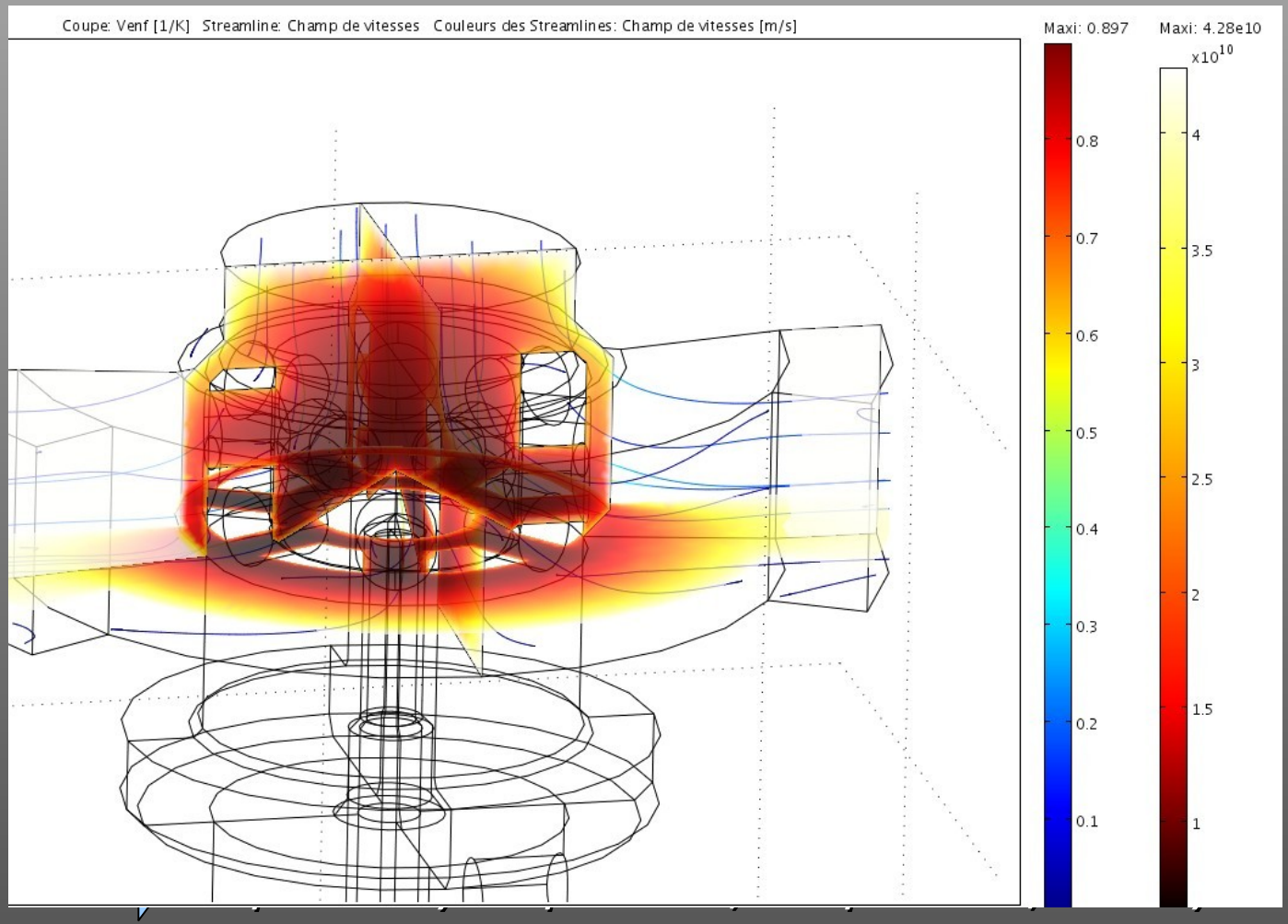
Collision frequency



Quantitative Results

Summary

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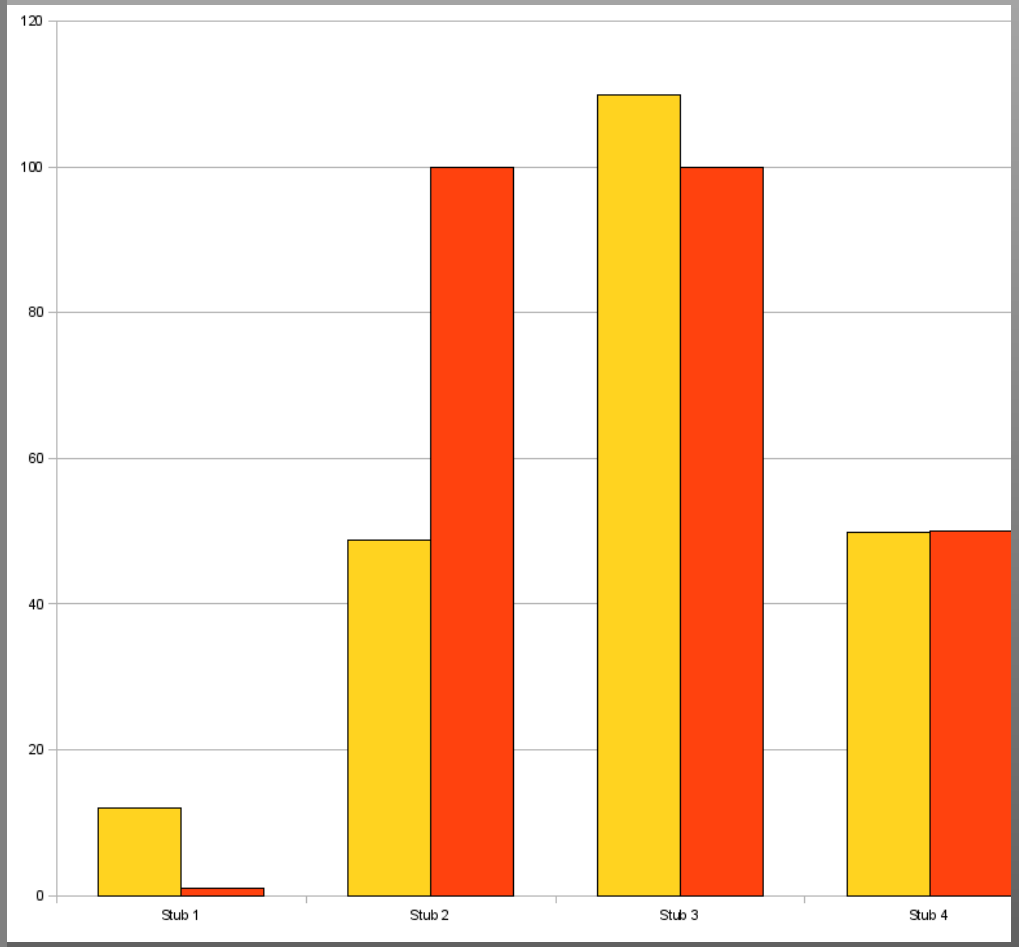

Comparison of simulated and measured reflected power

DOE results:

Gamma=10^{23}

$\nu_e = 1{,}8\ 10^{10}\ m^{-3}$

average value

Collision frequency is ok for nitrogen plasma

Good fitting for four working points / 1 parameters

Conclusions

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- We simulate a nitrogen microwave plasma
- We use a simplified plasma model (1 parameter)
- A DOE technique allow us to find a good agreement betwenn simulated and measurzed reflected power for four working points
- We will use this kind of model for development, design or optimization purpose
- We may improve model precision by using derive/diffusion

Thank you

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