SEVENTH FRAMEWORK PROGRAMME

DEECON

Brunel University London

Design of Microwave Cavity for Non-Thermal Plasma Generation

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COMSOL MULTIPHYSICS®

COMSOL CONFERENCE 2014 CAMBRIDGE

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- Non-Thermal Plasma Reactor
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Innovative After-Treatment System for Marine Diesel Engine Emission (DEECON)

EU

- FP7
- 2.3m Euro
- 3 years (2011 to 2014)
- 8 partners (UK, Italy and Poland)

Objectives

- NO_x < 2%
- SO_x <2%
- PM < 1% weight
- HC < 20%
- CO < 20%

Brunel

- Project leader – Professor Balachandran
- NOx and SOx Reduction using Non-Thermal Plasma

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Why NO_x and SO_x?

- Toxic gases
- Health issues
- International and National Regulations
- Sulpher Content
- Coastal area

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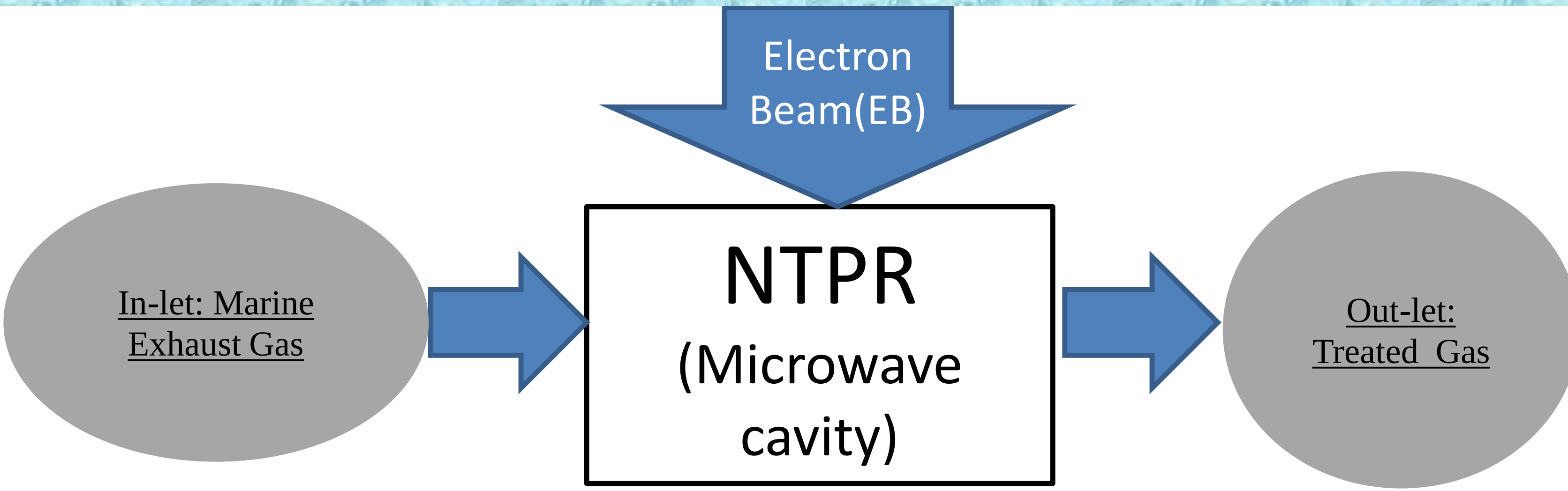
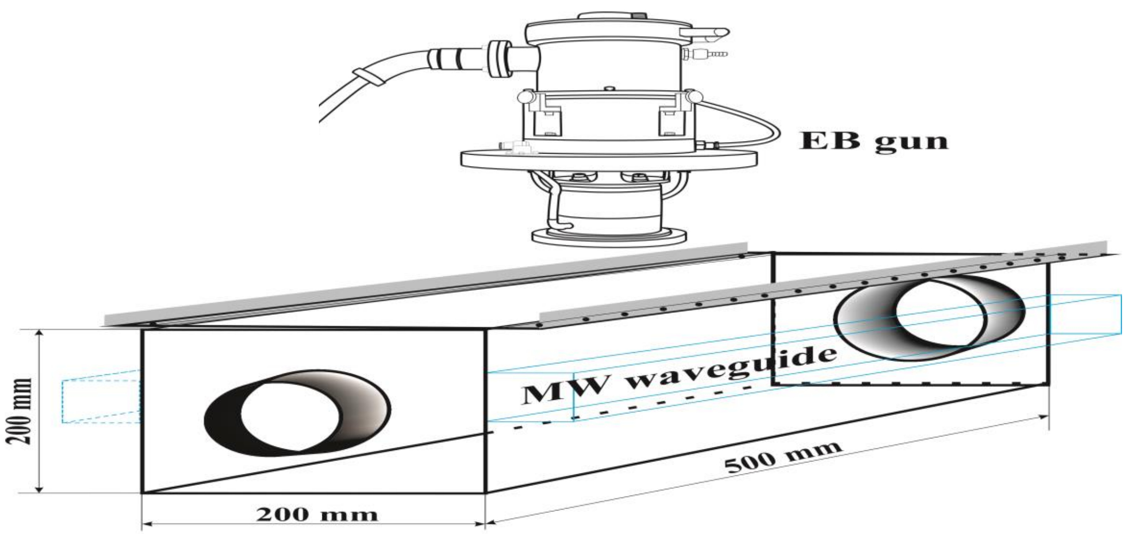
Non-Thermal Plasma Reactor (NTPR)



NTPR schematic



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Microwave Cavity design

- Maximum MW energy is transferred from magnetrons to the cavity
- Well spread electric field distribution – electrons from electron beam energized homogenously
- COMSOL FEM model for calculating electrified distribution

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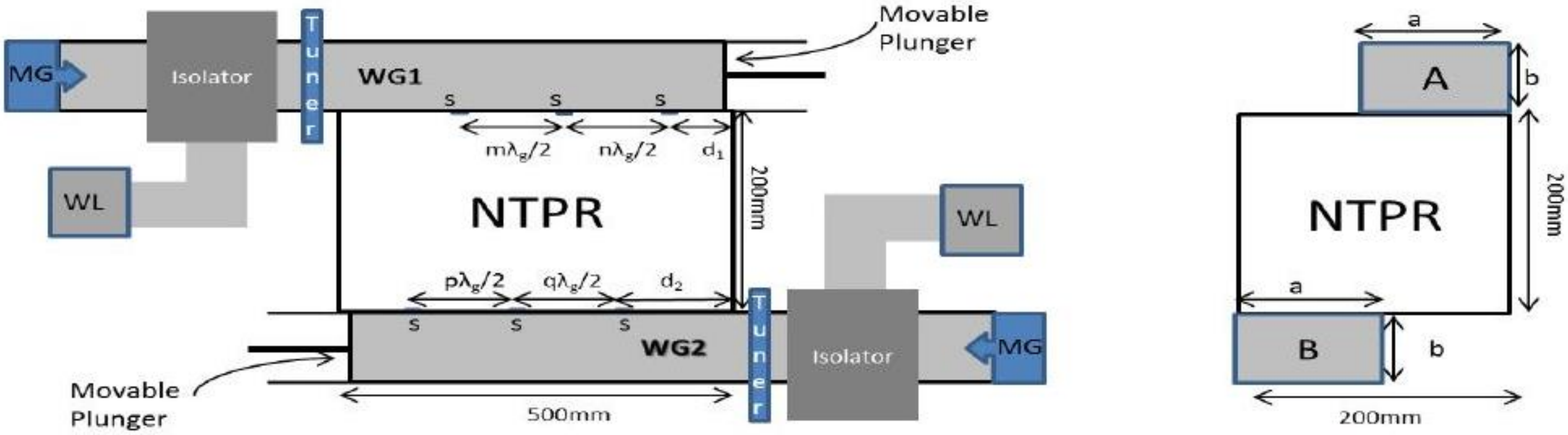
Proposed MW Scheme of NTPR



Top View

Side Elevation

MG : Magnetron (2.45GHz)
WL : Water Load
WG1 & WG2 :Wave guides (WR340 a= 109mm and b= 54.5mm)
S : Slots {2mm (width) x 109mm(height)}
λ_g : Wavelength of the waveguide (148mm)

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FEM Modelling and Simulation

COMSOL

Wave Guides

$2 \times$WR340:

(109mm$\times$55mm)

2×3 Slots

Microwave generation

2×2 kW, 2.45 GHz (S Band)

Simplified representation

NTPR

Rectangular cavity

200mm(w)$\times$200mm(h)$\times$500mm(l)

Physics

$$\nabla \times \mu_r^{-1}(\nabla \times \mathbf{E}) - K_0^2\left(\epsilon_r - \frac{j\sigma}{\omega\epsilon_0}\right)\mathbf{E} = \mathbf{0}$$

μ_r - permeability ; ε_0 - permittivity; **E** - electric field vector; σ - density and K_0 – wave number.

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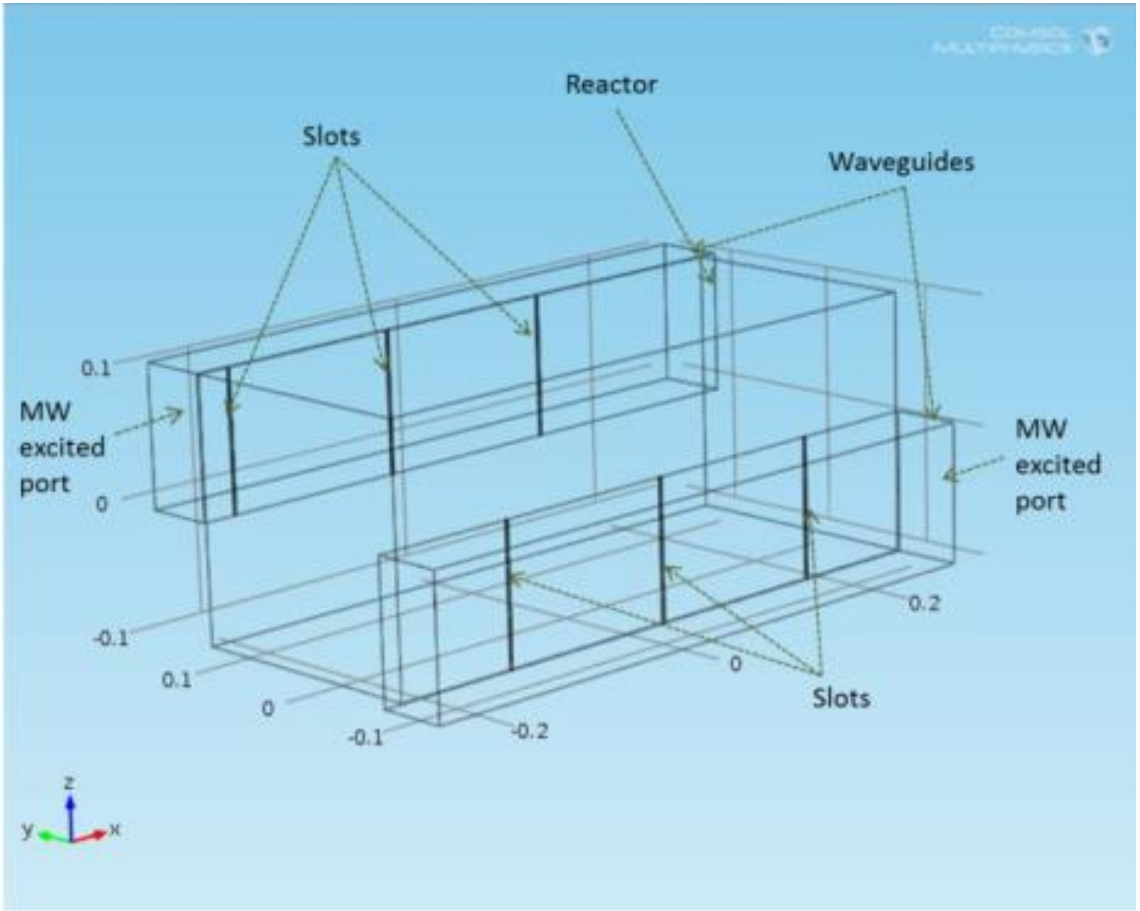
FEM Modelling - Geometry



- Parameterized dimensions
- Simplified Model
- MW excited port
- User defined meshed

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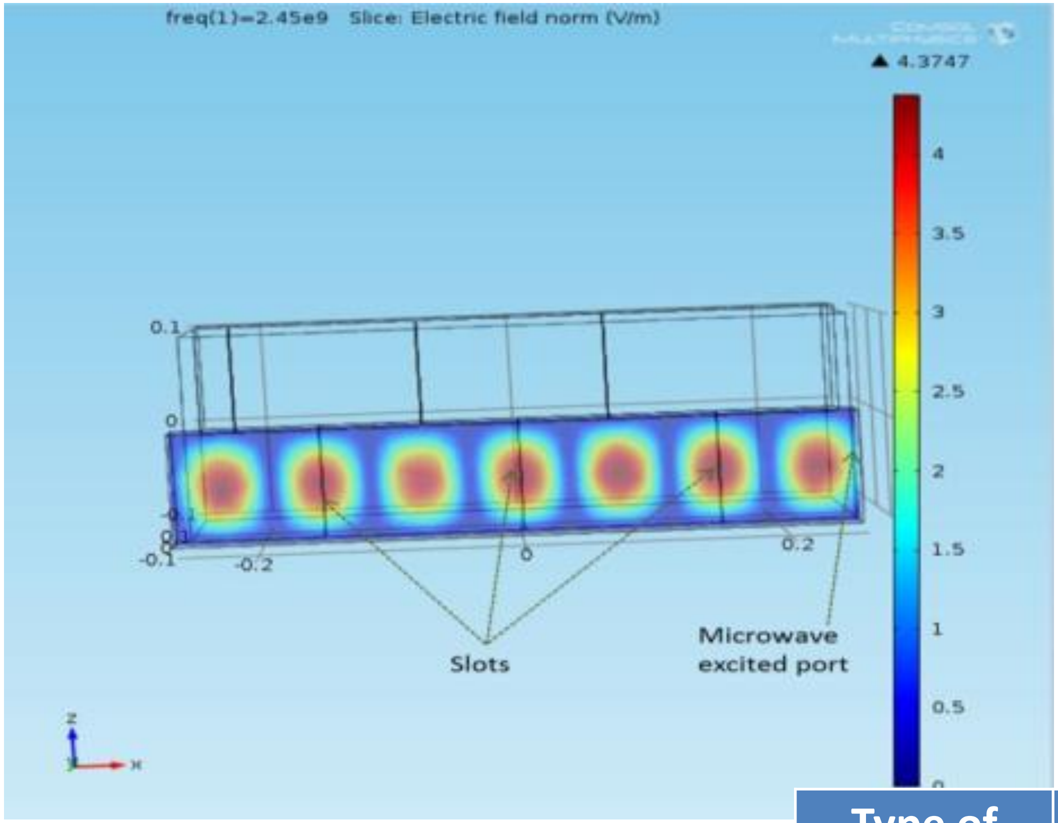
FEM Modelling – Position of slots



Waveguide Equations TE10

$$\lambda_g = \frac{\lambda_o}{\sqrt{1 - \left(\frac{\lambda_o}{2a}\right)^2}}$$

λ_g = wavelength of waveguide
λ_o = wavelength of microwave (= 122mm)
a = longest side of the rectangular cross section

- Slot position s are at high intensity region (HIR)
- HIR can be adjusted by varying the length of the waveguide (Operation of plunger)

Type of wave guide	Dimensions (mm)	λ_o (mm)	λ_g (mm)	distance between slots
WR 430	109 × 55	122	148	74
WR 340	86 × 43	122	173	86.5

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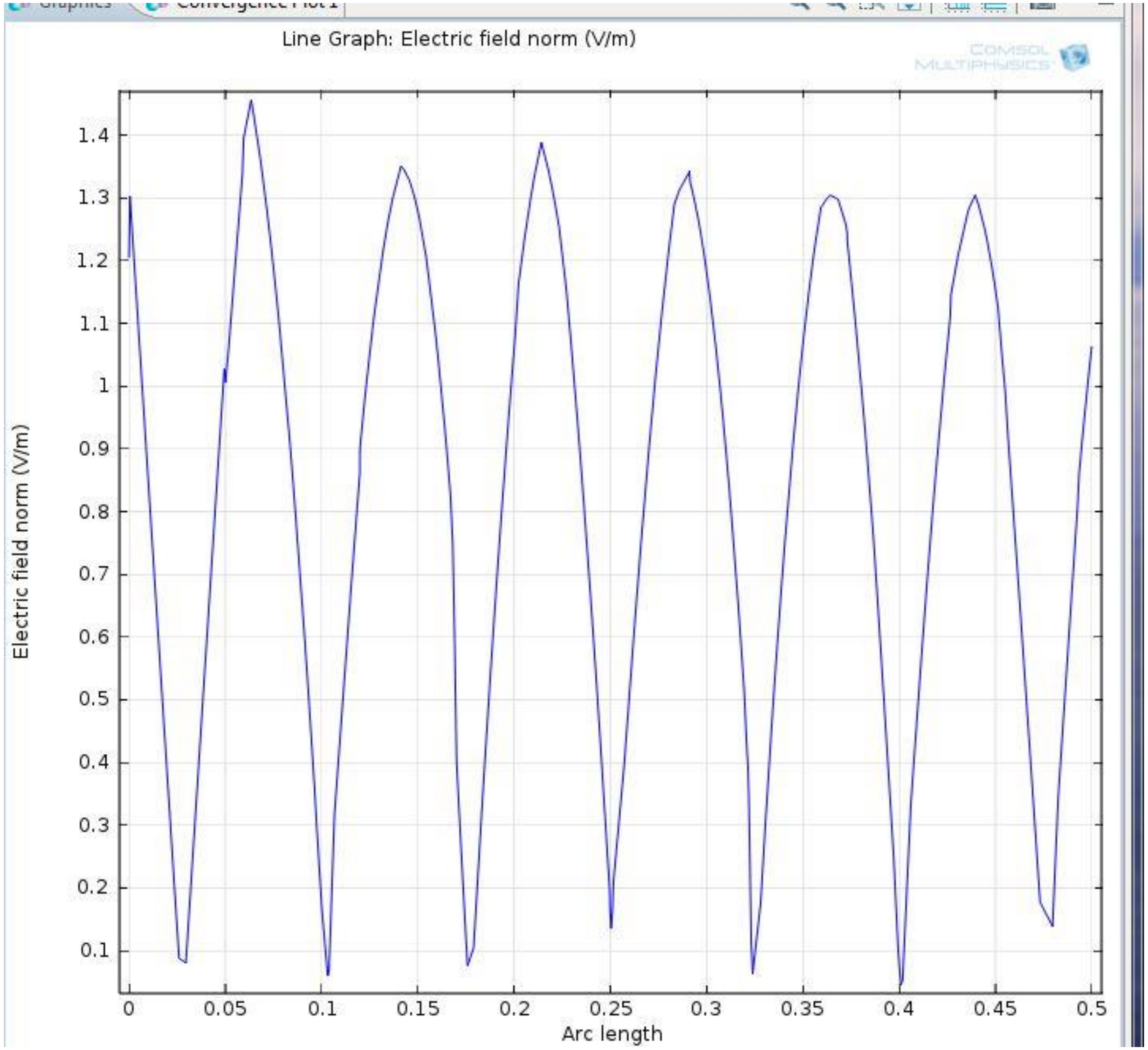
FEM Modelling – Line scans across the wave guide



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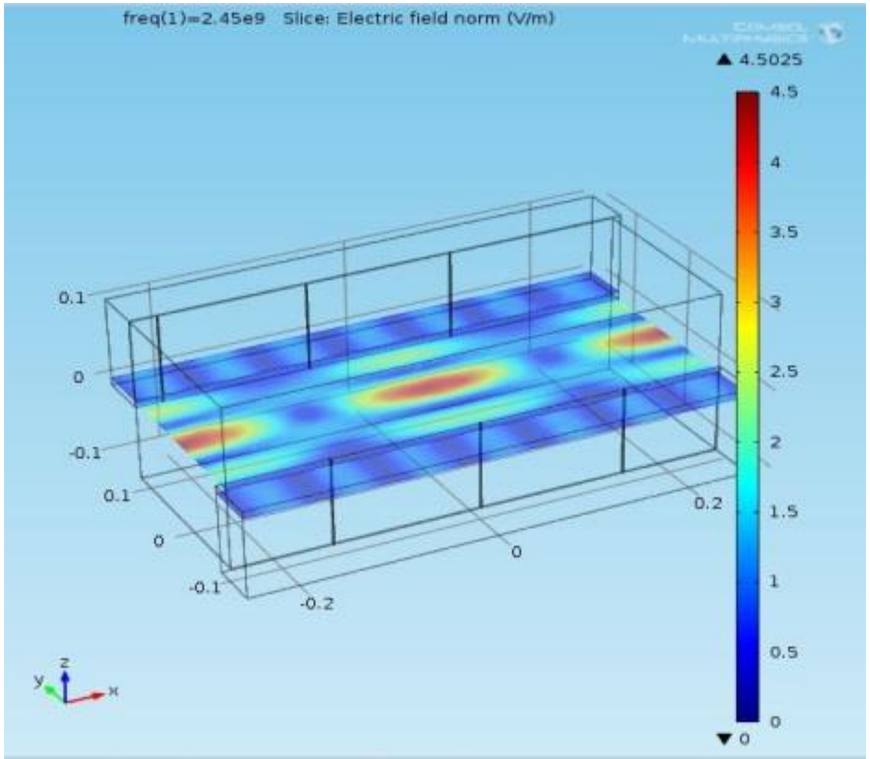
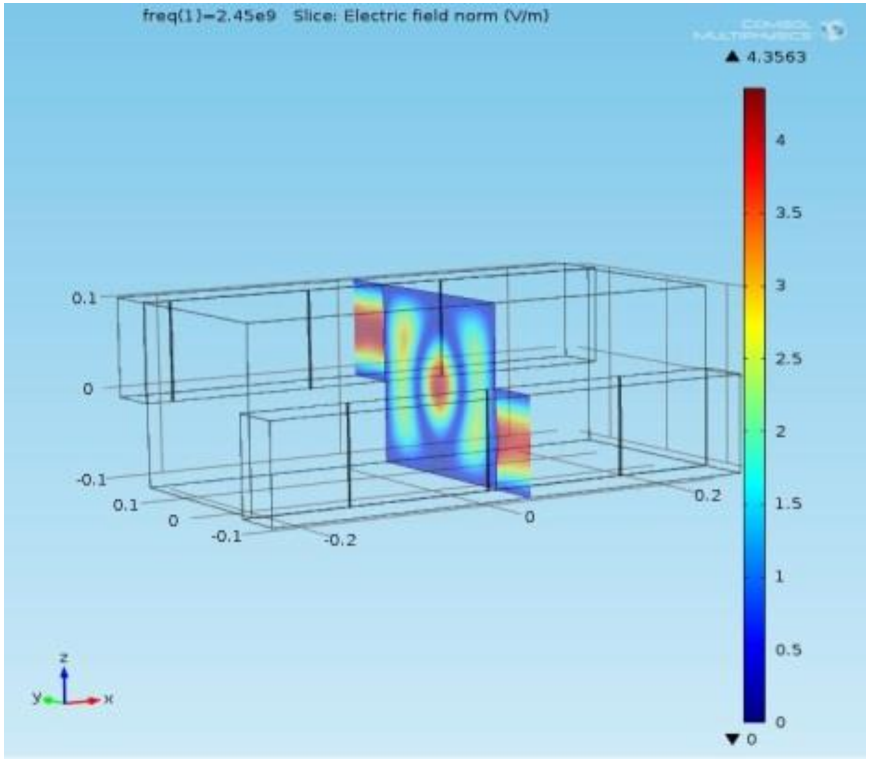
Some FEM Modelling Results





- High electric field regions in the NTPR reflects the high energy electron plasma region

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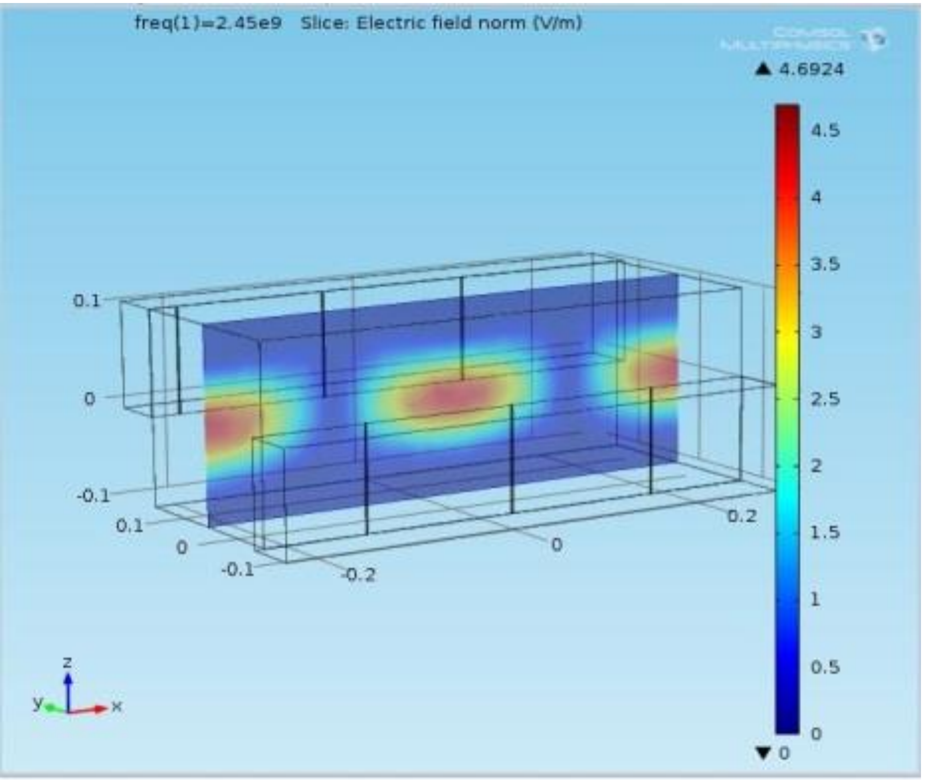
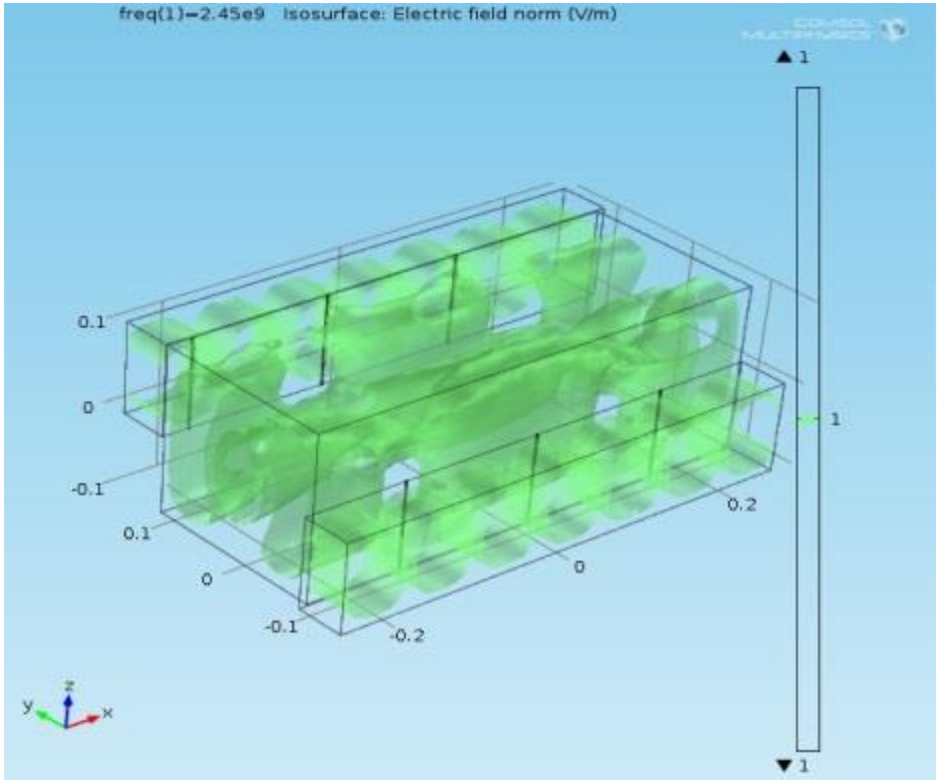
Some FEM Modelling Results





- Isosurface plots shows high intensity regions

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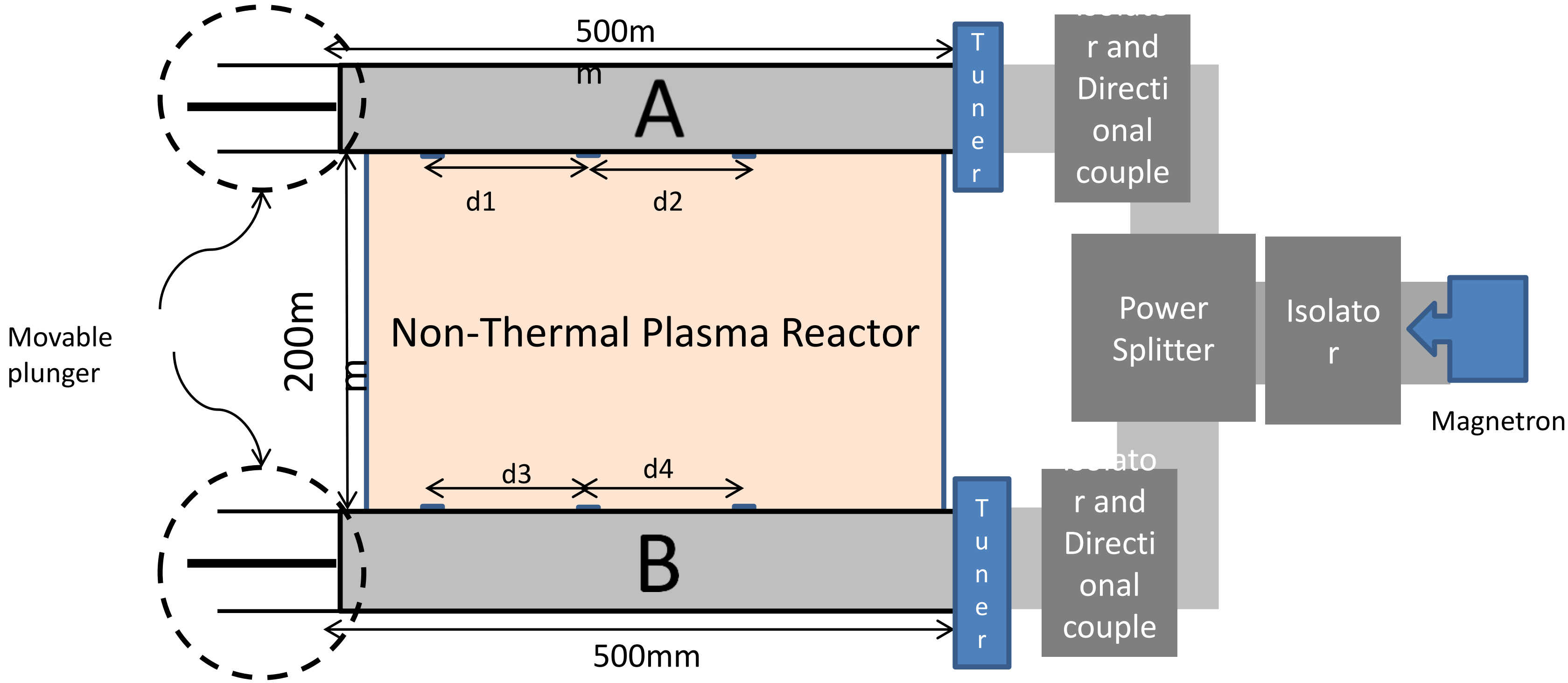
Other MW arrangements



A & B - Straight wave guide (WR340)
S1, S2, S3, S4, S5, S6 – slots
d1, d2, d3, d4 – distances integer multiples of half the wave length of the wave guide

Depth of the reactor = 250mm

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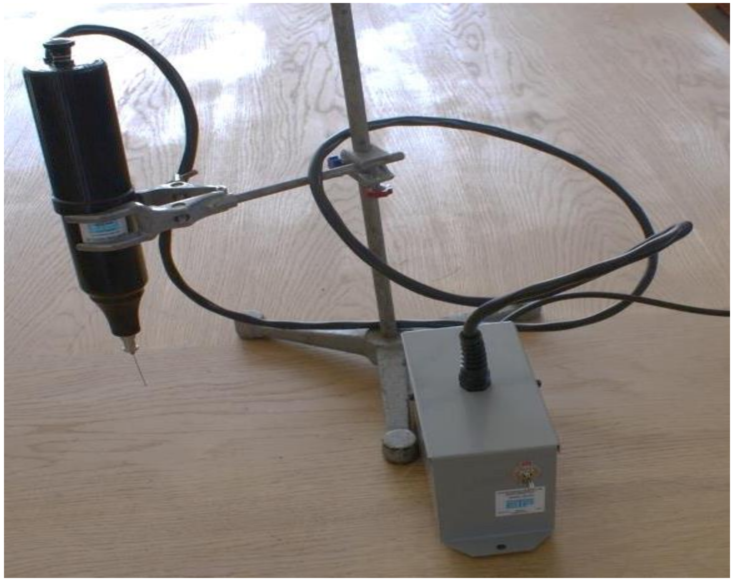
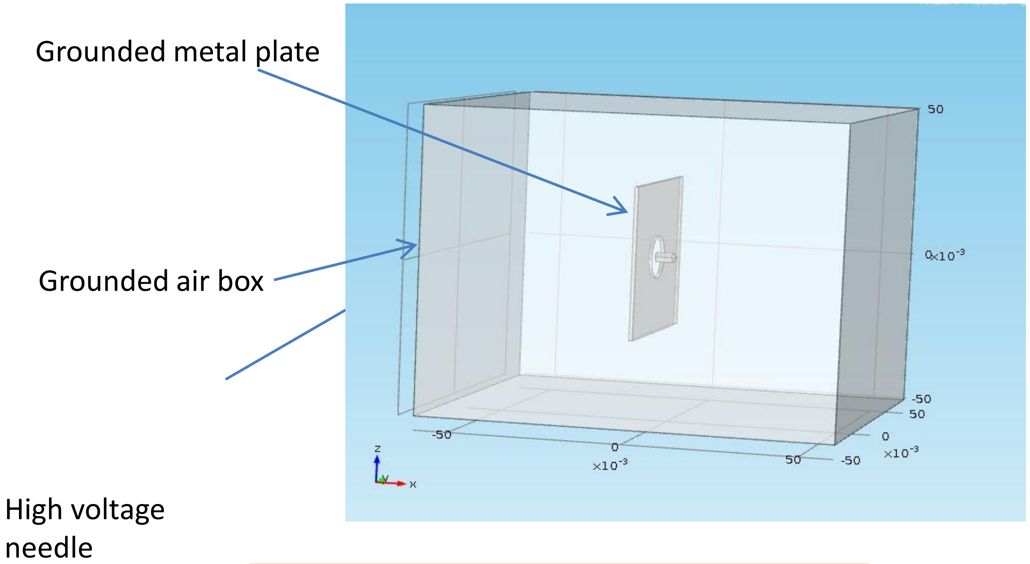
Corona source and COMSOL modelling



Commercial DC Corona source



Simplified COMSOL geometry

Parameter	Value
High voltage needle dimensions	Diameter of the cylindrical section – 3.15mm Length of the cylindrical section – 5mm Length of the conical section - 1mm
Grounded plate dimensions	5mm (length) x 5mm (width) x 1mm (thickness)
Distance between tip of the high voltage and the grounded plate	5mm
High voltage	48kV

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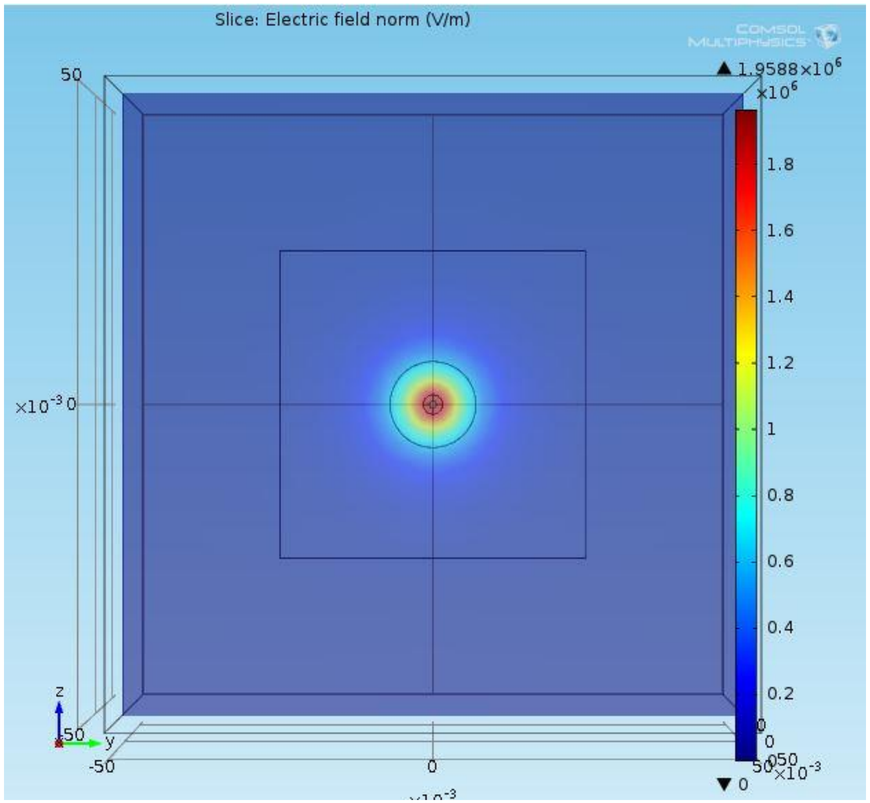
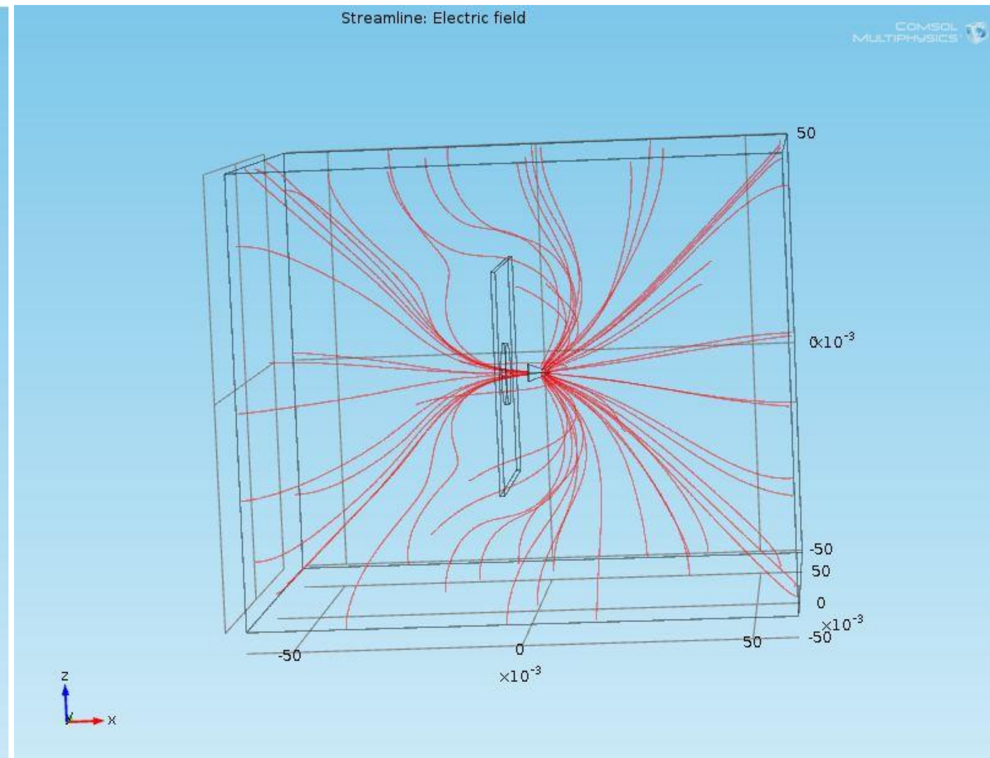
Some FEM Modelling Results





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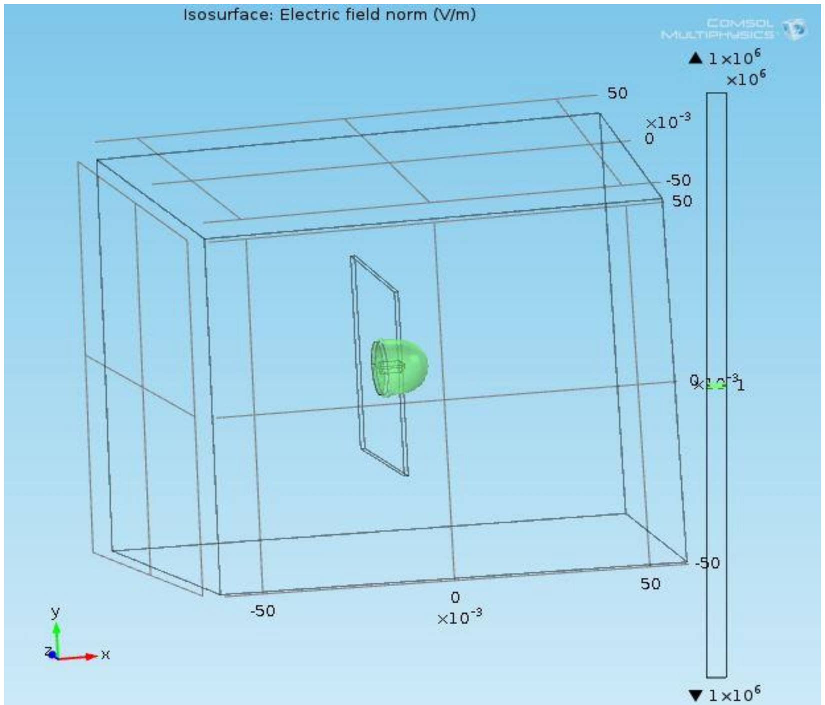
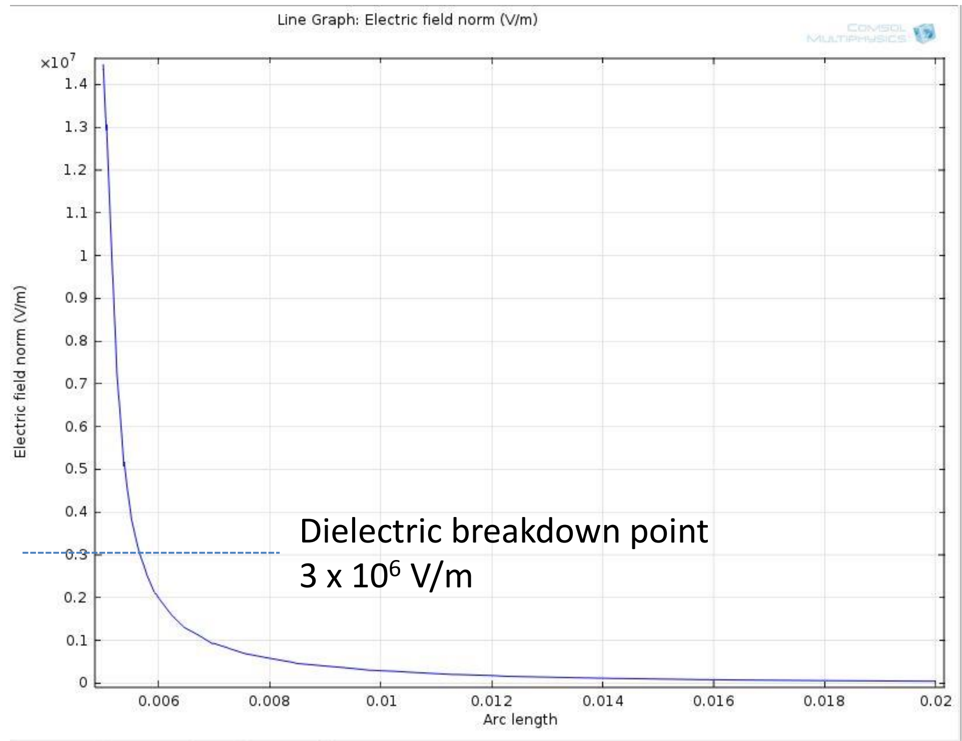
Dielectric Break Down of Air





- Dielectric breakdown will occur within 1cm region from the needle
- Plasma exists for more than 1cm region
- Microwave can then spread plasma to a wider region

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NTPR in the Pilot Scale Test Site Southampton

Conclusions

- Non-Thermal Plasma for emission control
- Microwave multimode cavity with slotted waveguide is designed with COMSOL
- Corona source was used generate plasma, also investigated using COMSOL

Thank You