COMSOL CONFERENCE ROTTERDAM2013

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Influence of electrical conductivity and plasma pressure on temperature distribution and acoustical eigenfrequencies of high-intensity discharge (HID) lamps

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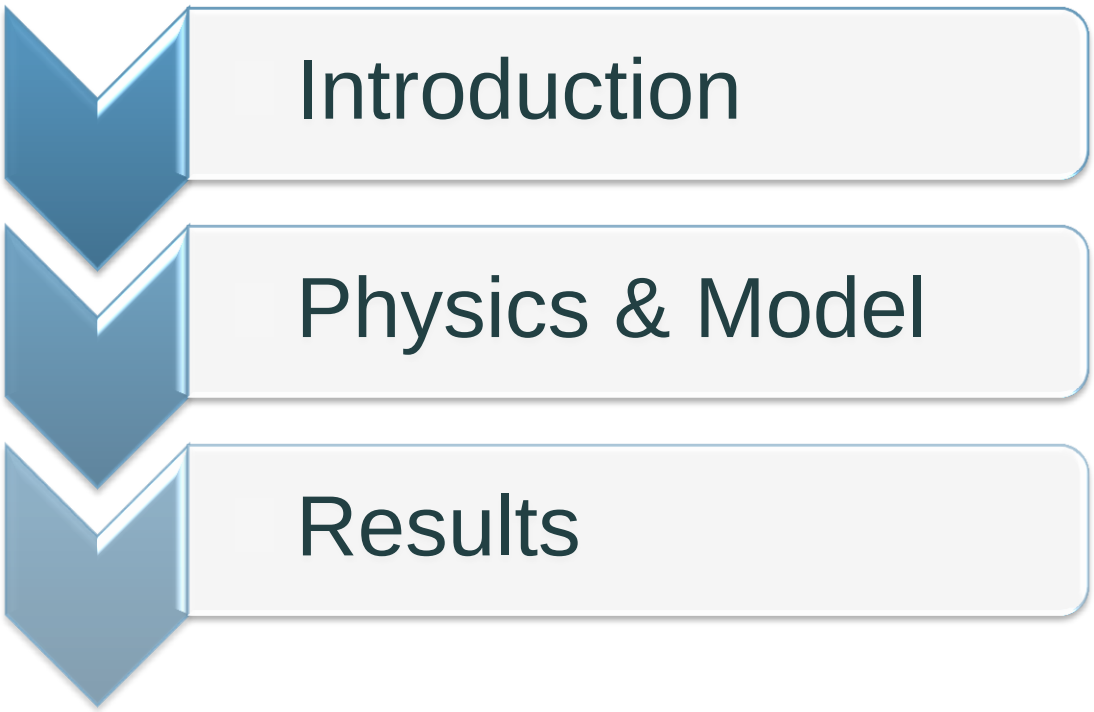
Agenda



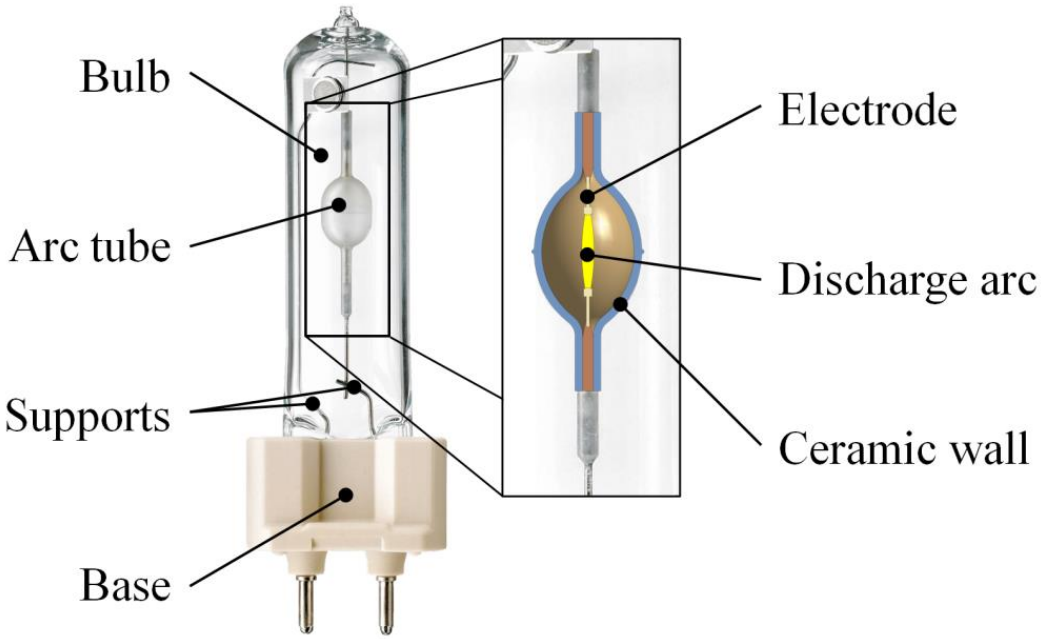
HID lamp

Applications

- Street lights
- Industrial lights
- Automobile headlights

Main advantages

- Solar like luminance density
- High efficacy



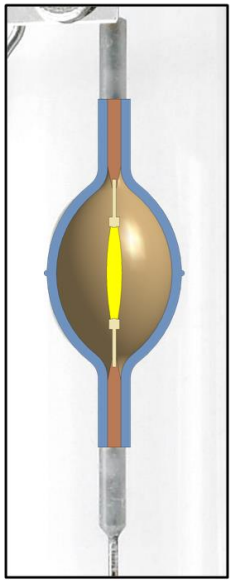
Arc tube

- Discharge arc: Light emission by excited atoms
- Filling: Hg, Ar and metal halides
- Static pressure: Atmospheric or higher

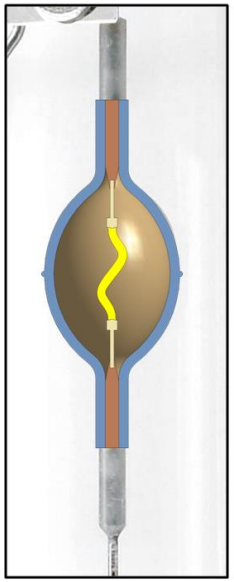
Problem description

- Increased energy effciency
- High frequency AC operation
- Oscillating heat source
- Alternating temperature and pressure
- Excitation of acoustic resonances (at EF)
- Arc flickering possible
- Lamp destruction possible

Straight



Distorted



Simulation physics

Charge conservation

$$\vec{\nabla}\cdot\left(-\sigma\vec{E}\right)=0$$

Electric field

Elenbaas-Heller equation

$$\vec{\nabla}\cdot\left(-\kappa\vec{\nabla}T\right)+\rho c_p\vec{u}\cdot\vec{\nabla}T=\sigma\left|\vec{E}\right|^2-\vec{q}_{rad}$$

Temperature field with conduction and convection terms

Navier-Stokes equation

$$\rho\left(\vec{u}\cdot\vec{\nabla}\right)\vec{u}=\vec{\nabla}\cdot\left[-p\vec{I}+\eta\left(\vec{\nabla}\vec{u}+\left(\vec{\nabla}\vec{u}\right)^T\right)\right]+\vec{F}$$

Fluid velocity field under influence of gravity and pressure

Stationary

$$T(x,y,z)$$

Wave equation

$$\vec{\nabla}^2 p+\left(\frac{\omega}{c}\right)^2 p=0 \qquad c=f(T)$$

Eigenfrequencies and –modes

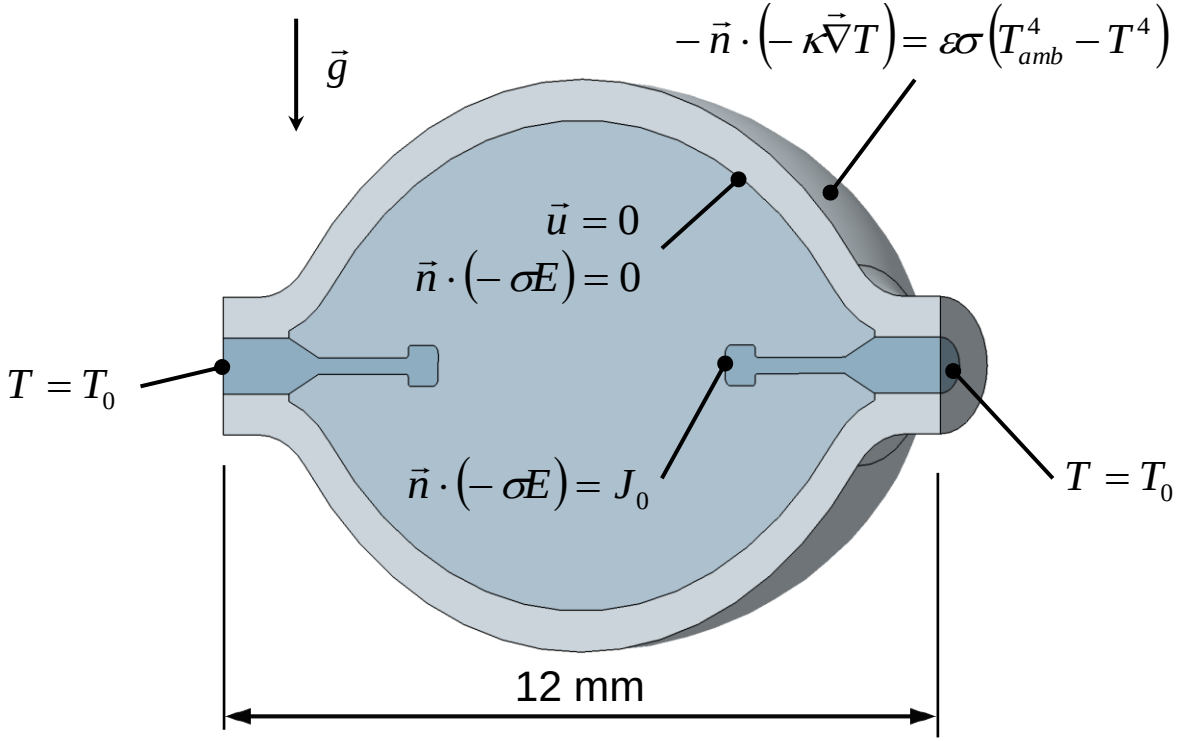
Eigenfrequency

Simulation model

- HID lamp: Philips® 35W/930 Elite
- 3D symmetric model
- Horizontally positioned symmetry axis

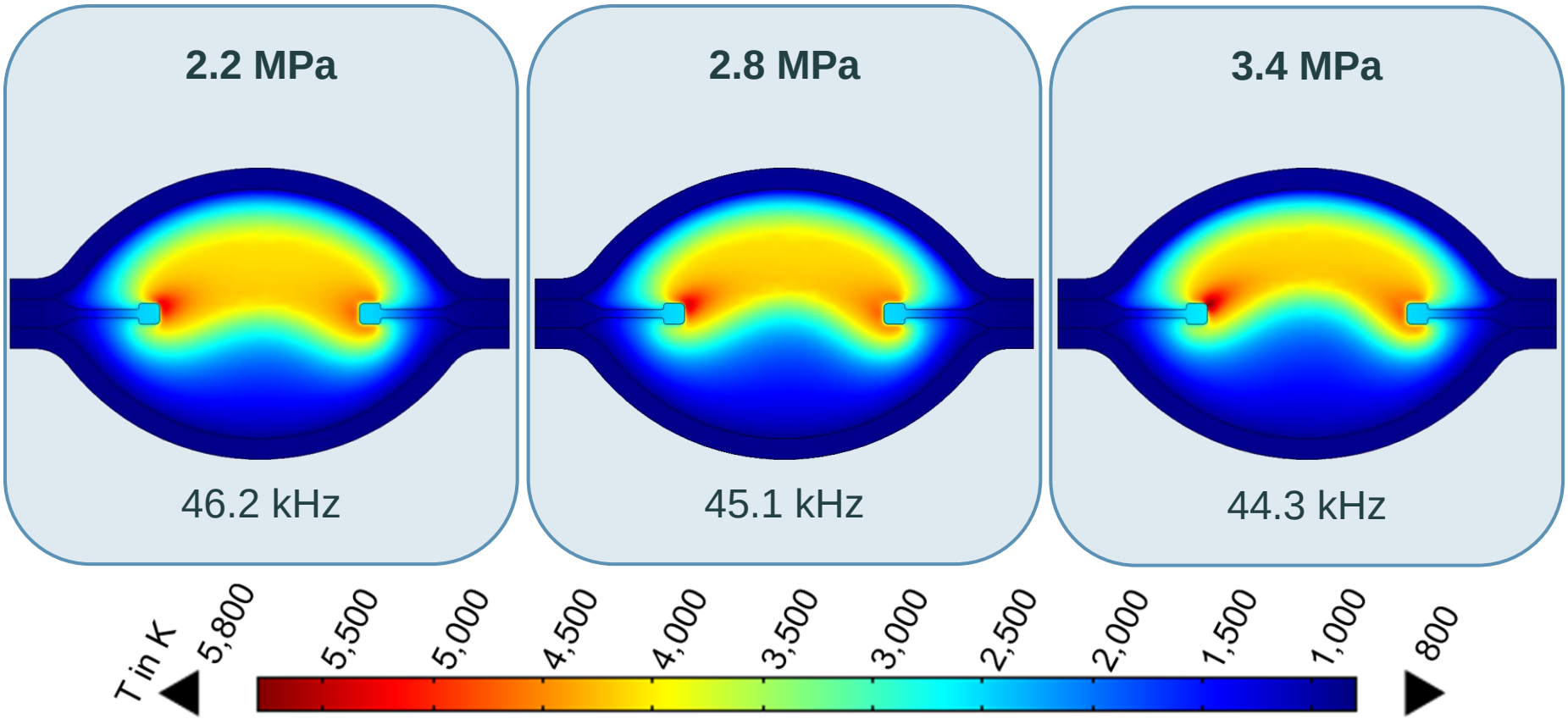
Boundary conditions

- Electric insulation
- Wall
- Constant temperature
- Heat radiation



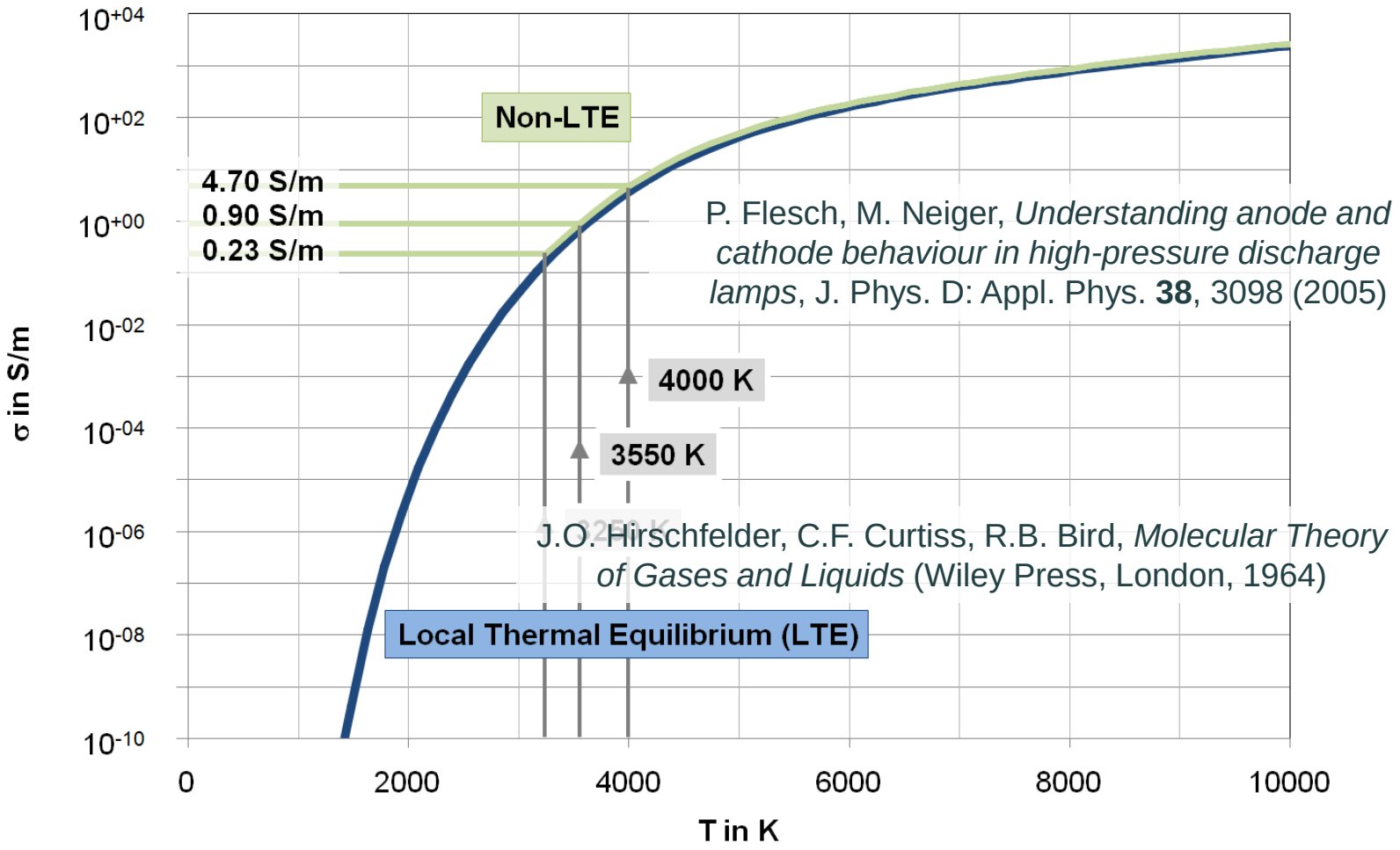
Results

Influence of plasma pressure



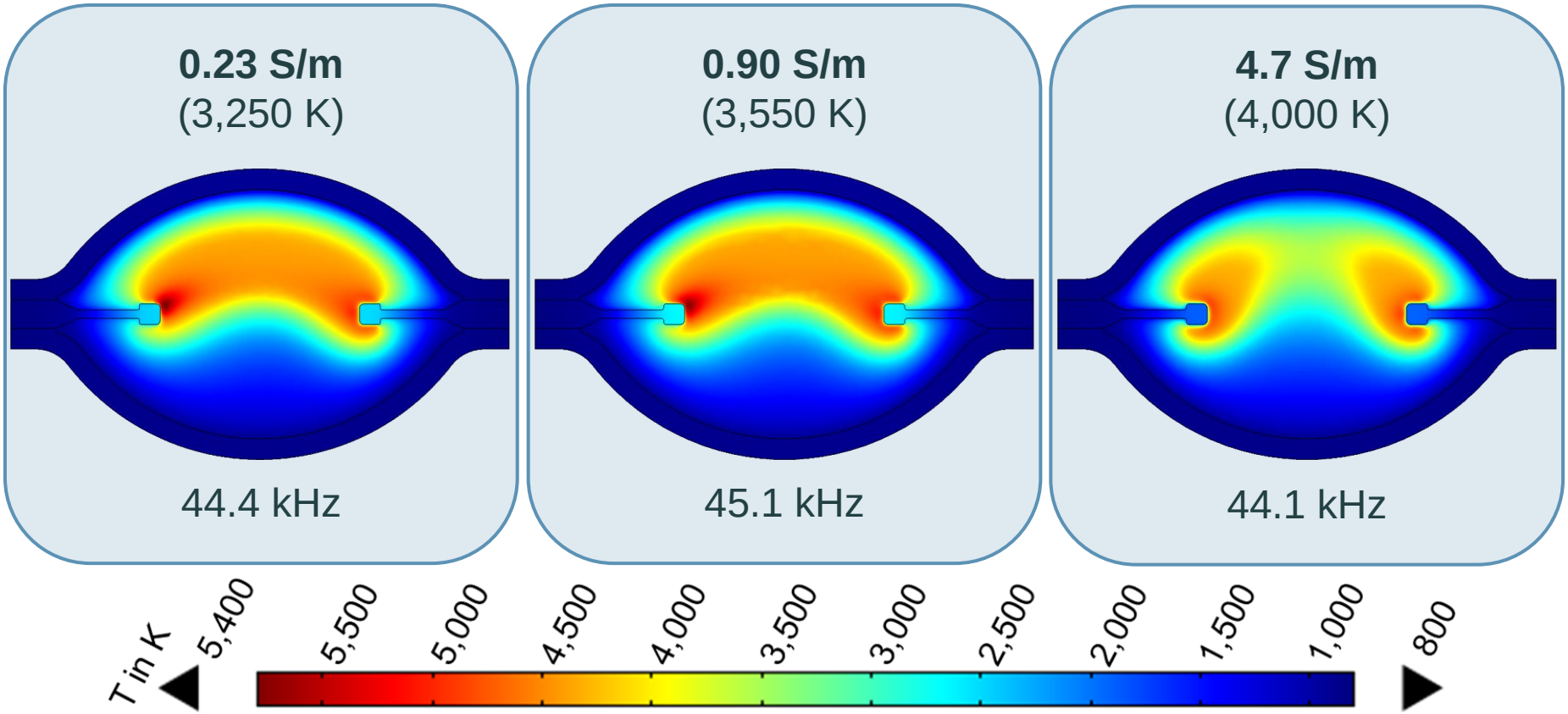
- **Temperature distribution: Higher pressure → larger arc deflection**
- **Acoustical eigenfrequency: Slight decrease at increasing pressure**

Influence of electrical conductivity



Results

Influence of electrical conductivity



- **Temperature distribution: Significant change at 1.0 S/m**
- **Acoustical eigenfrequency: Small changes**

Conclusions

- Influence of plasma pressure and electrical conductivity:
  - ➢ Minor changes in Eigenfrequencies
  - ➢ Major changes in temperature distribution

Experimental validation

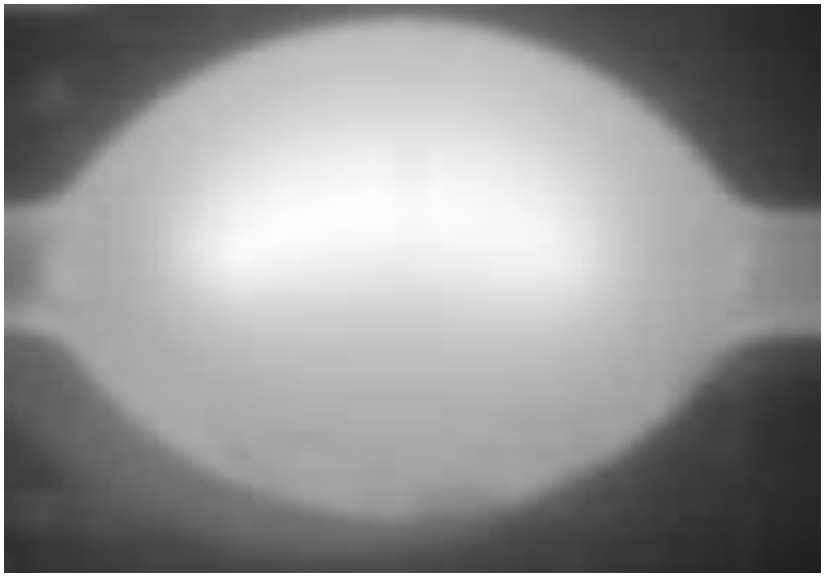
➔ Observation of light emitting arc with camera

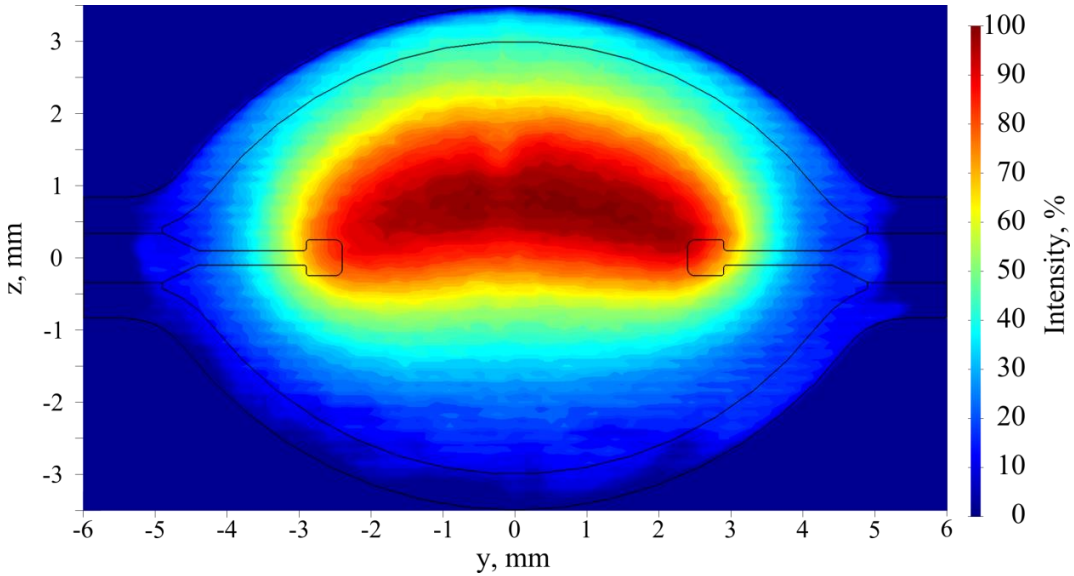
Thank you for your attention.

Backup

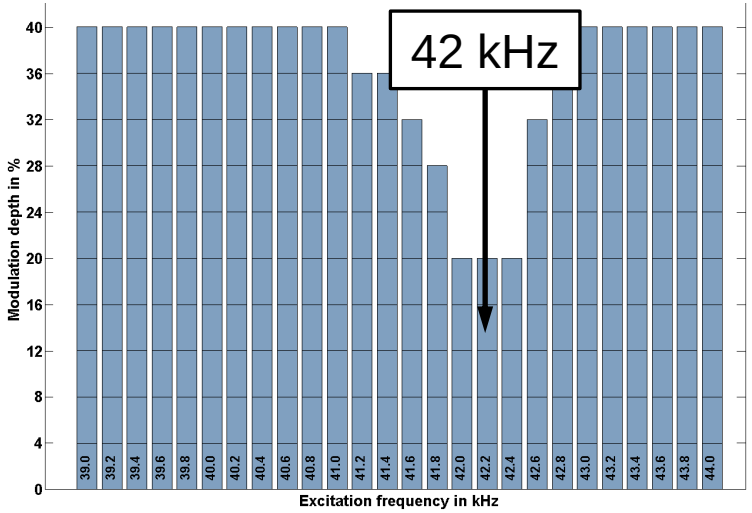
Experimental results

Light intensity distribution





Eigenfrequency



Simulation

Stationary analysis

- Steep electric potential profile at electrode
- Joule heating source
- Buoyancy driven flow