Influence of Pre-discharge on Soft X-ray Amplification in the Fast Gas-filled-capillary Discharge

Jiří Schmidt

Capillary Experiment (CAPEX)

• source of soft X-ray radiation based on the fast capillary discharge
• Pulse Plasma Department, IPP AS CR, Prague
• K. Koláček, V. Boháček, O. Frolov, V. Prukner, M. Řípa, J. Schmidt, J. Štraus, P. Šunka, P. Vrba, …
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• Experimental set-up of CAPEX

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• Experimental results

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Experiment CAPEX

- capillary current amplitude: 45 kA
- period of capillary current: 240 ns
- current rise-time: $>10^{12}$ A/s
- gas-filled capillary: argon
- amplification of Ne-like Ar line (3p-3s, J=0-1): 46.9 nm
Experimental set-up of CAPEX

MARX GENERATOR
- 8 stages
- erected capacity 12.5 nF
- short-circuit inductance 14.2 µH
- erected voltage 400 kV

SPACER (coupling section)
- SF₆ as a dielectric
- capacitance 10 pF
- inductance 95 nH
- a safety interface
Experimental set-up of CAPEX

FAST CAPACITOR
- distilled water as a dielectric
- capacitance 6.0 nF
- inductance 68 nH
- char. impedance 3.4 Ω
- dimensions φ262 x φ158 x 675 mm

SPARK GAP
- inner part filled by SF₆ gas
- outer part filled by destilled water (for capacity enlargement)
Capillary

- ceramic capillary (**alumina**)
- capillary diameter 3.2 mm
- capillary discharge length up to 180 mm
- gas-filled capillary argon
- filled by a needle valve (**continuous flow**)
- capillary current **amplitude** 45 kA
- **period** of capillary current 240 ns
- current rise-time >$10^{12}$ A/s
CAPEX experiment
Spark gap region

- no plastic circular ring \((\text{pre-pulse} > 50\text{A})\)
- plastic circular ring of medium thickness \((\text{pre-pulse} \sim 10-50 \text{A})\)
- plastic circular ring of full thickness with suitably reduced outer diameter \((\text{pre-pulse} 1-30 \text{A})\)
- plastic circular ring of full thickness (outer part of the spark gap without water) \((\text{pre-pulse} 0.5-1 \text{A})\)
- without auxiliary electrode located in water \((\text{no observed pre-pulse})\)
**Spark gap region**

- **no plastic circular ring**  
  \((\text{pre-pulse} > 50\text{A})\)

- **plastic circular ring of medium thickness**  
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- **plastic circular ring of full thickness with suitably reduced outer diameter**  
  \((\text{pre-pulse} 1-30\text{ A})\)

- **plastic circular ring of full thickness**  
  (outer part of the spark gap without water)  
  \((\text{pre-pulse} 0.5-1\text{ A})\)

- **without auxiliary electrode located in water**  
  \((\text{no observed pre-pulse})\)

- **Water**  
  \(\varepsilon_i=80\)

- **SF\(_6\)**

- **Insulator**
Spark gap region

- no plastic circular ring (pre-pulse > 50A)
- plastic circular ring of medium thickness (pre-pulse ~ 10-50 A)
- plastic circular ring of full thickness with suitably reduced outer diameter (pre-pulse 1-30 A)
- plastic circular ring of full thickness (outer part of the spark gap without water) (pre-pulse 0.5-1 A)
- without auxiliary electrode located in water (no observed pre-pulse)
Spark gap region

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  \textit{\textbf{(pre-pulse > 50A)}}

- plastic circular ring of medium thickness
  \textit{\textbf{(pre-pulse ~ 10-50 A)}}

- plastic circular ring of full thickness
  with suitably reduced outer diameter
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  (outer part of the spark gap without water) \( (pre-pulse \, 0.5-1 \, \text{A}) \)

- without auxiliary electrode located in water 
  \( (no \, observed \, pre-pulse) \)
Capillary pre-pulse current
without spark gap breakdown

no plastic circular ring
(pre-pulse > 50A)
Capillary pre-pulse current
with spark gap breakdown (t=0)

no plastic circular ring
(pre-pulse > 50A)
Experimental results

Measurements of the soft X-ray radiation

• temporal evolution of the soft X-ray radiation measured by PIN-diode

• soft X-ray spectrum measured by home-made flat field spectrometer
**Spectroscopic measurements**

**Home-made soft X-ray flat field spectrometer**

- entrance slit adjustable in vacuum: 0-500 µm
- toroidal grating Jobin Yvon: 450 gr/mm
- average groove density: 919.0 mm
- tangential radius: 102.57 mm
- sagital radius: 34x12 mm
- upper surface dimensions: 30x8 mm
- ruled area dimensions: 10-110 nm
- spectral interval: 40x5 mm
- focused on rectangle: 2 MCPs (33x33x1 mm) clear 30 mm (in tandem set-up)
- “phosphor” screen: ITO/ZnS
- detection: CCD camera PCO SensiCam 1280x1024 pixels
Spectroscopic measurements

time-resolved spectrum (50 ns)

- time-resolved spectrum
  (1 kV/50 ns pulse opening MCP detector)
- amplitude of pre-pulse 5 A
- pre-pulse duration 0.9 µs
- initial pressure of argon ~80 Pa
Spectroscopic measurements

time-resolved spectrum (50 ns)

- time-resolved spectrum
  (1 kV/50 ns pulse opening MCP detector)
- amplitude of pre-pulse  5 A
- pre-pulse duration  0.9 µs
- initial pressure of argon  ~80 Pa
Conclusions

- an influence of the pre-pulse current on an amplification of Ne-like Ar line ($\lambda=46.9$ nm) was studied

- several configurations of the spark gap was tested (changing of the pre-pulse current in the range of 0 to 60 A)

- a strong amplification of Ne-like Ar line ($\lambda=46.9$ nm) was observed for the pre-pulse current amplitude of 5 A

- the time-resolved spectrum (50 ns) was obtained by home-made soft X-ray flat field spectrometer

Plan for a future

- a shorter exposition (10 ns) of the time-resolved spectrum are desirable

- measurement with an other spectrograph (which has a better resolution)