University of California, Los Angeles

Experimental study of flibe vapor condensation

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Town Meeting on IFE Liquid Wall Chamber Dynamics

Livermore, CA

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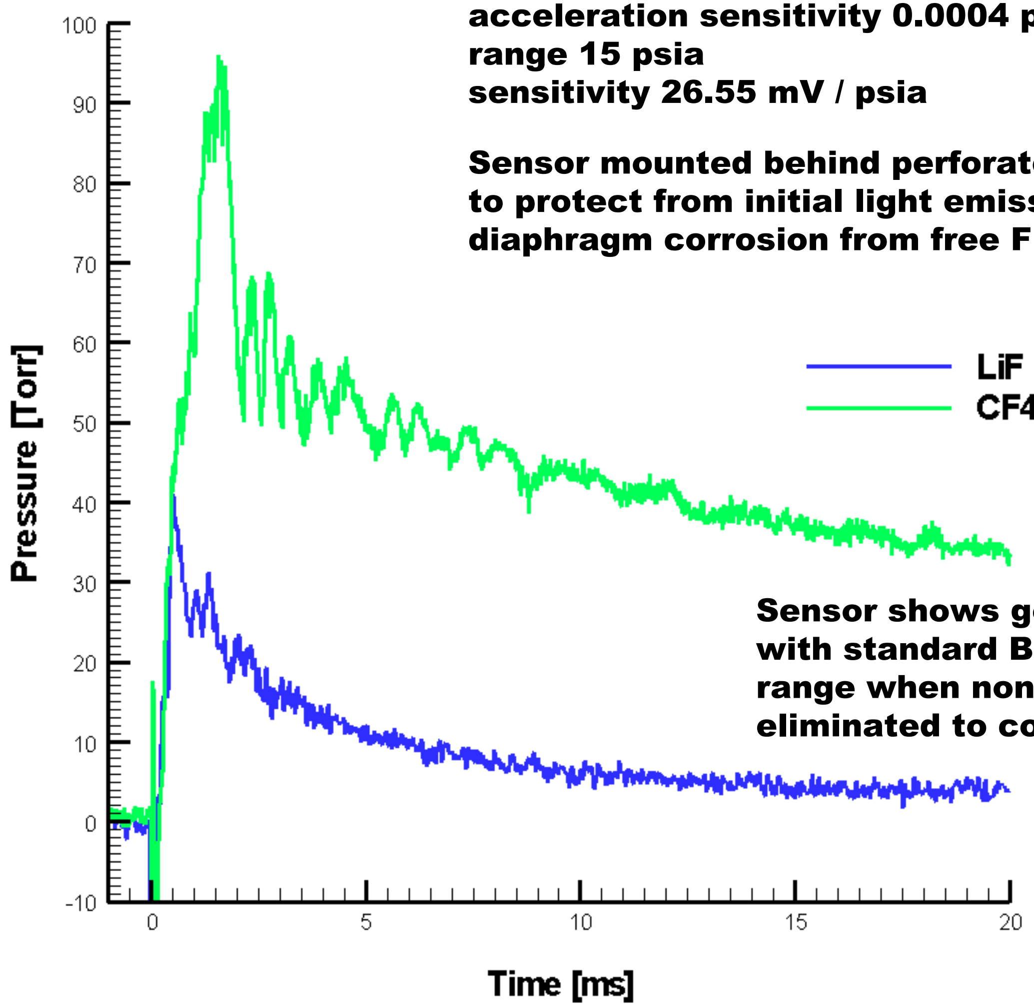
Staged implementation of Flibe use

Flibe handling

Stage I Source testing	Stage II Diagnostic	Stage III
Transparent plastic chamber for easy visualization (low T)	SS chamber with view ports, insertion ports and heater for high T	flibe 2/3 LiF + 1/3 BeF_2 in moles
Materials: • plastic polycarbonate (Lexan) • Teflon (CF_2 molecular chain) • Metals (Tin, Al) • Flibe	Spectroscopy: • Teflon (CF_2 molecular chain) • LiF Pressure history - non condensable gases: • LiF	Total amount of purified flibe available for experiments: 1 liter from INEEL Casting disks with ¼ inch central bore for plasma source sleeve

Chamber pressure history

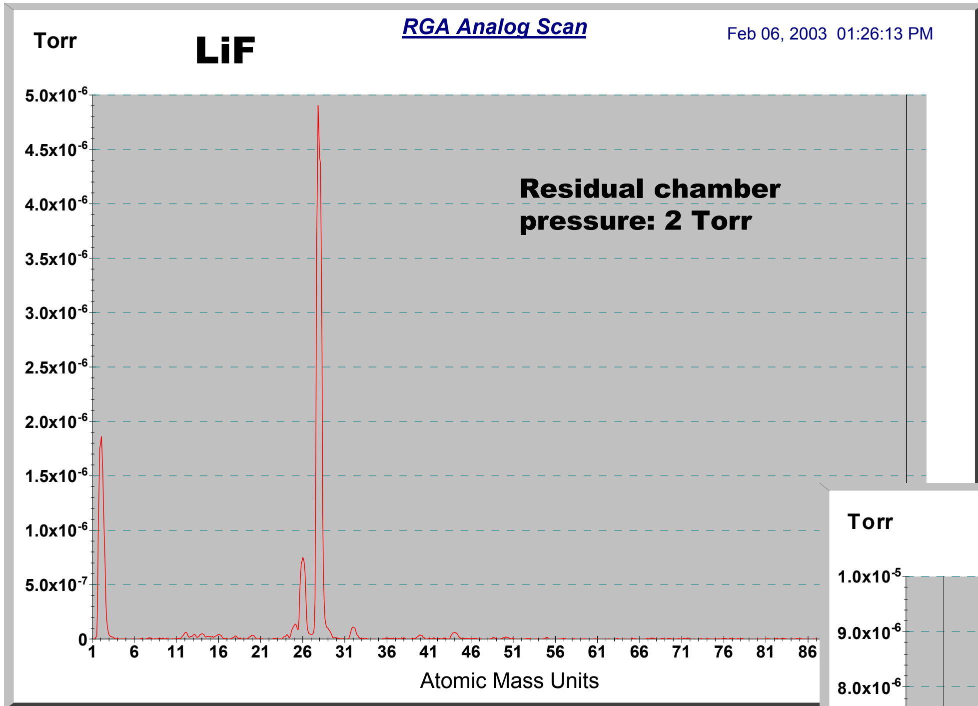


Endevco absolute sensor 8540-15:
resonant frequency 140 kHz
acceleration sensitivity 0.0004 psi / g
range 15 psia
sensitivity 26.55 mV / psia

Sensor mounted behind perforated screen to protect from initial light emission and diaphragm corrosion from free F

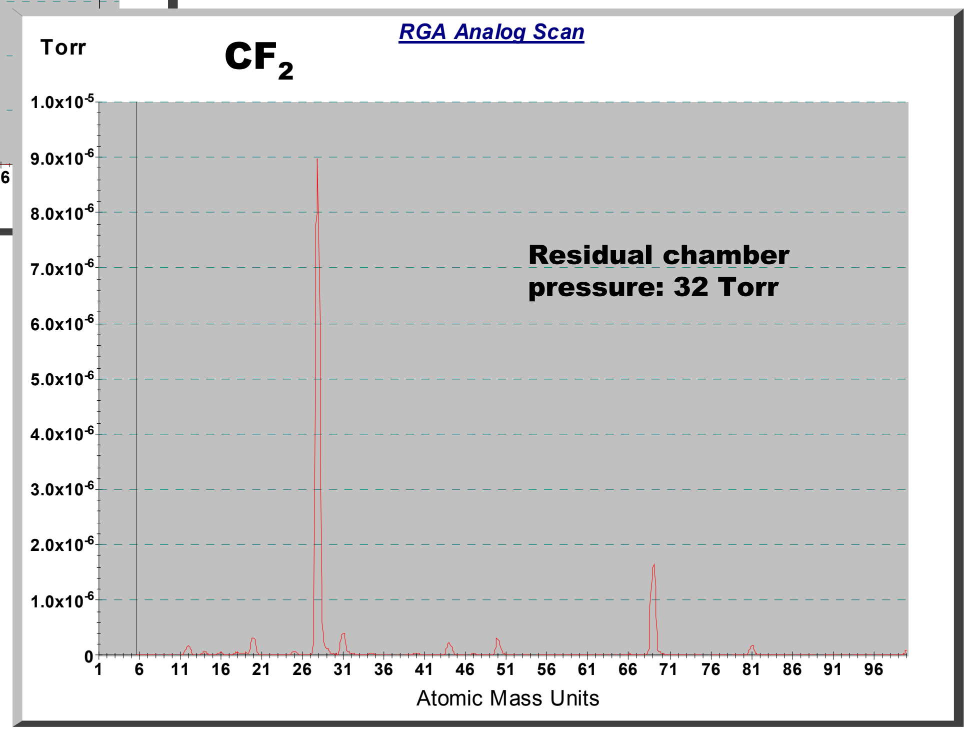
Sensor shows good sensitivity - it will be coupled with standard Baratron sensors in the 0 - 1 Torr range when non condensable gases are eliminated to compete the pressure history curve

Mass spectroscopy for residual gases analysis



28 peak accounts in both cases for more than 50% of the total pressure. It is a complex peak that accumulates contributions from N_2, CO, CO_2 and traces of more complex hydrocarbons such as ethane

Air (Nitrogen) can be evaluated by the 14 peak of dissociated N

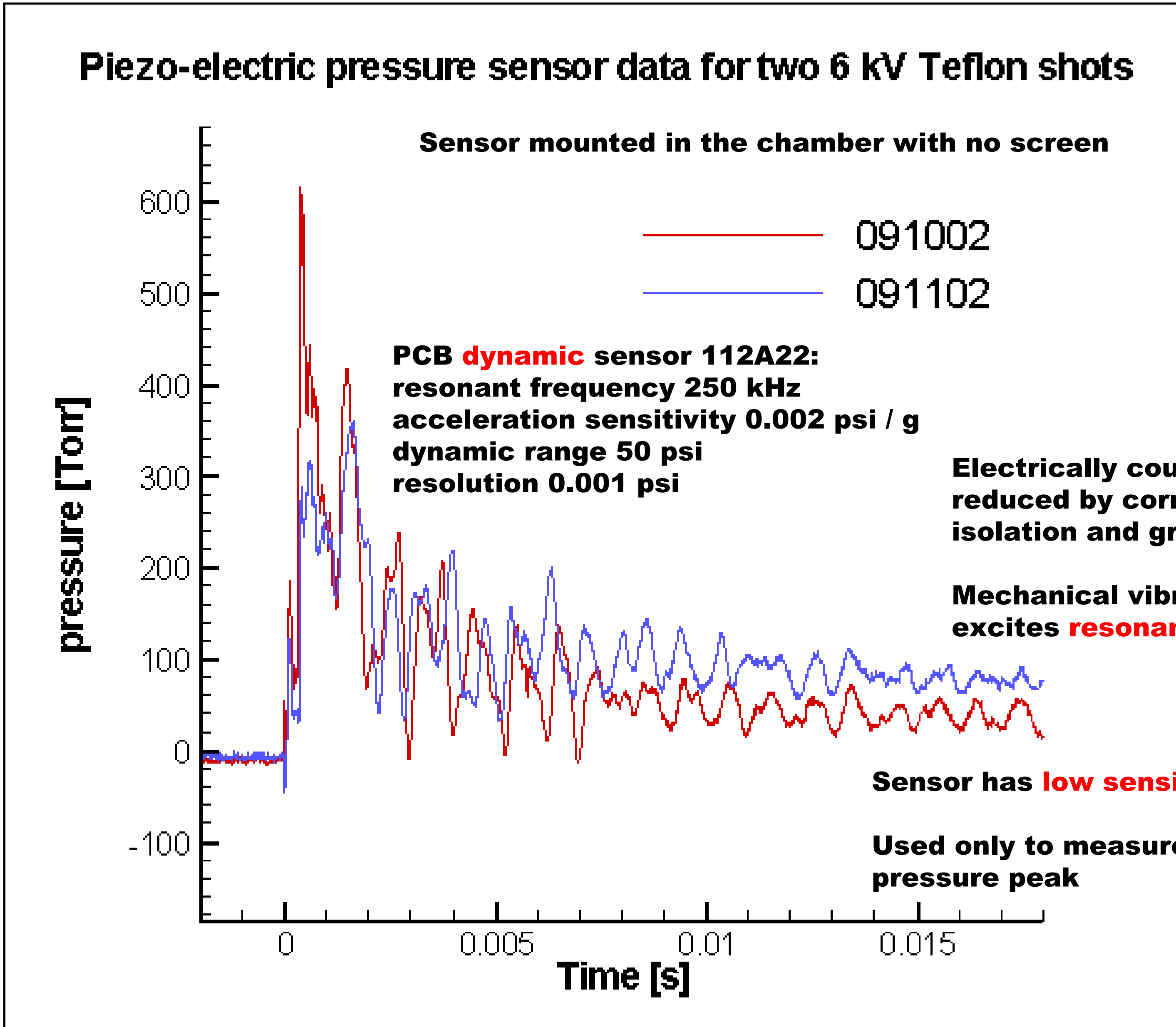


Residual gas composition in the chamber for LiF shot evaluated with RGA correction factors:

CO, CO_2, Hydrocarbons: 1100 mTorr
N_2: 180 mTorr
HO_2: 40 mTorr
O_2: 30 mTorr

LiF: 180 mTorr

Chamber pressure history



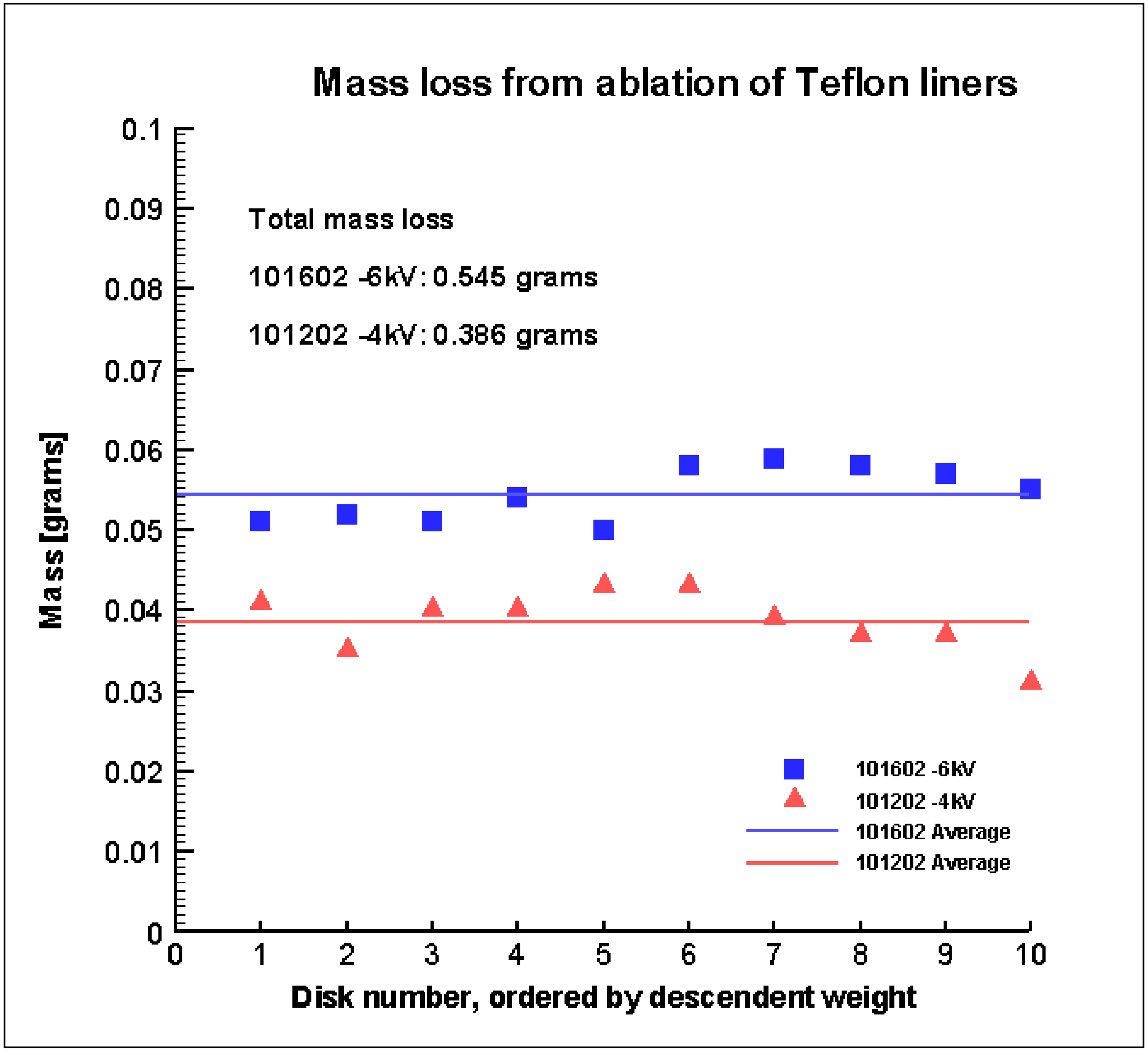
Electrically coupled noise reduced by correct isolation and grounding

Mechanical vibration excites resonant noise

Sensor has low sensitivity

Used only to measure initial pressure peak

Sleeve ablated mass: CF_2 experiments



The electro-thermal source

Characterization of superheated vapor generation shows measured parameters similar to SIRENS

Typical vapor parameters in the source :

$n = 10^{19} - 10^{20}$ # / cm^3
T = 1-3 eV

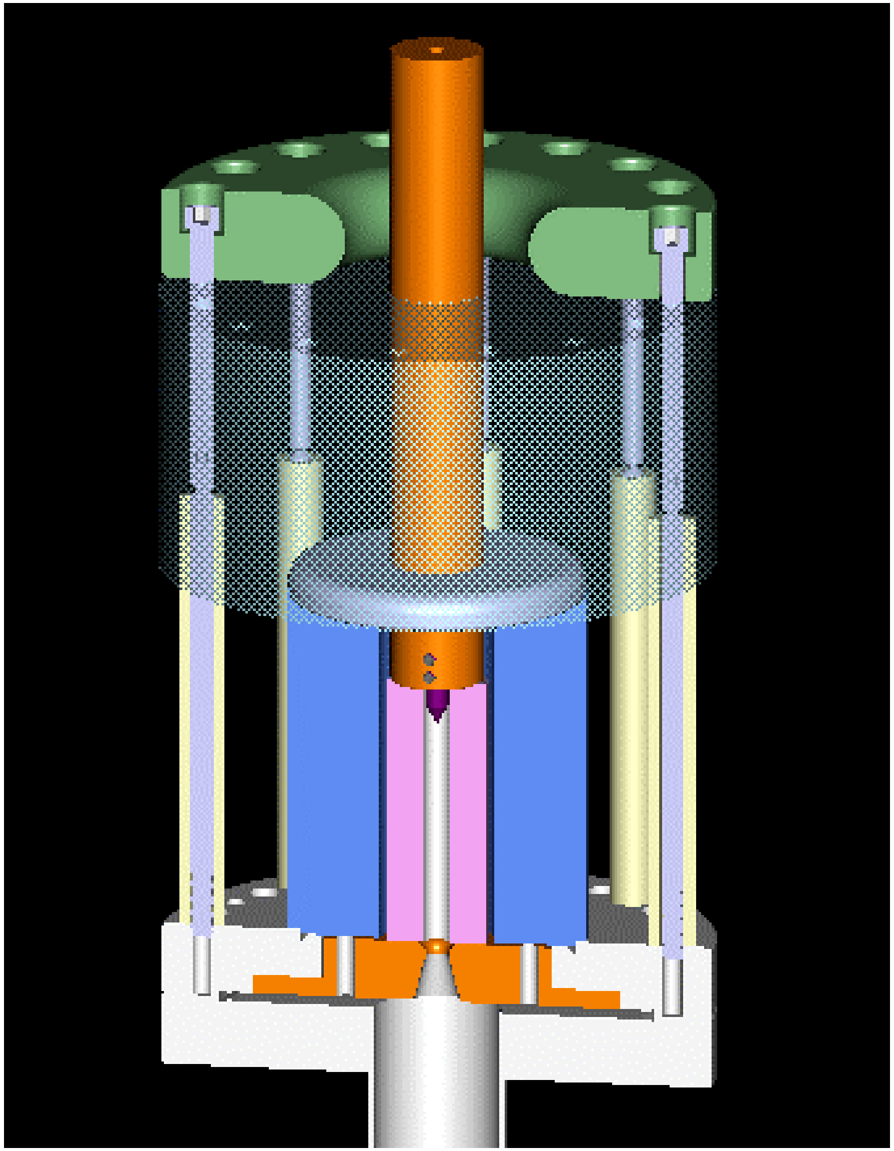
Close Ignitron switch

Cu triggering wire vaporizes (10-100 nanos) forming initial plasma column

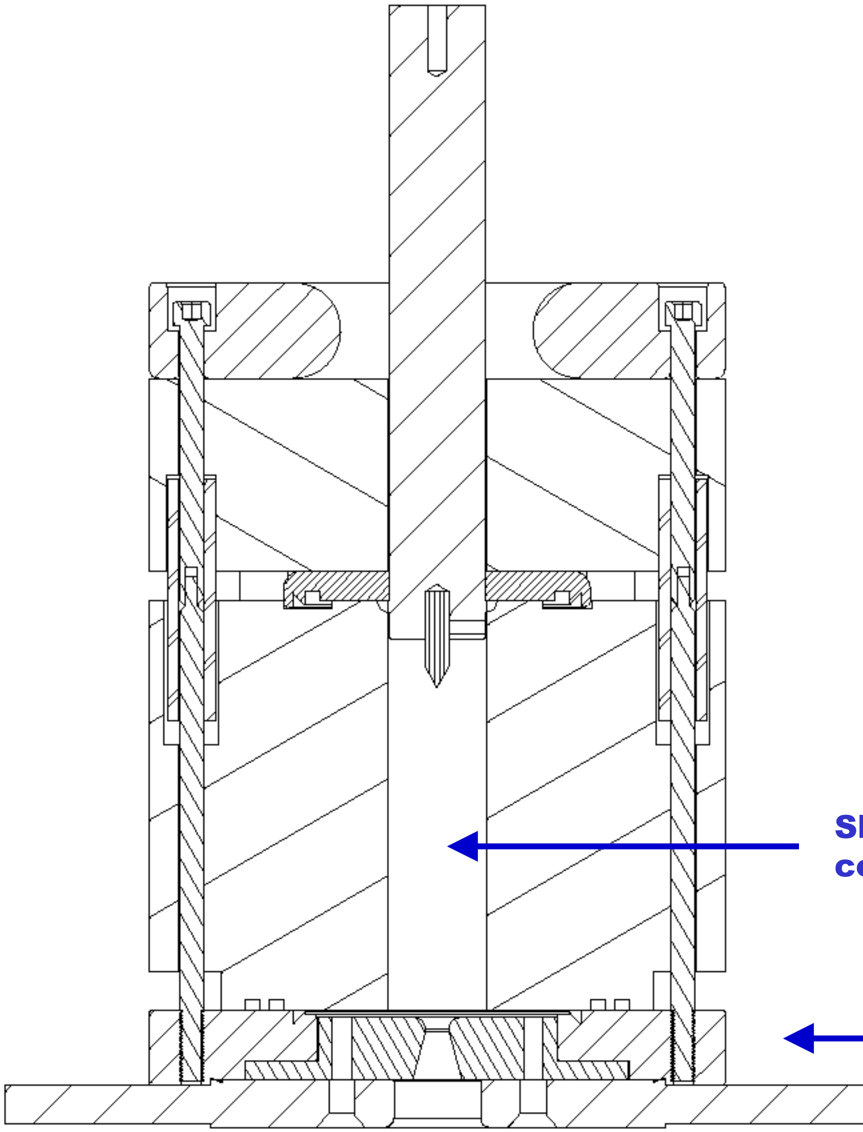
Energy stored in cap banks maintains plasma at 1-3 eV for 100 micros

Injected electrical power radiated to surface, ablates material of interest

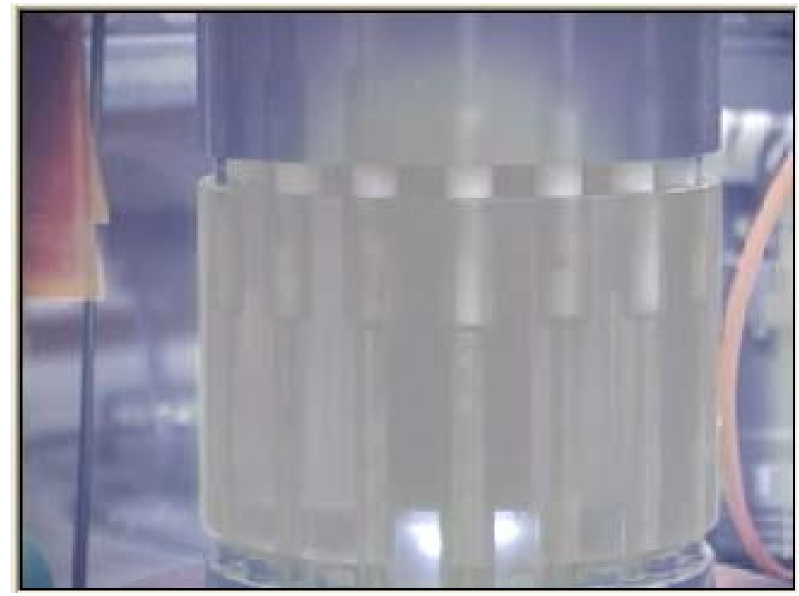
Pressure gradient drives injection, ablation balances axial mass loss



The electro-thermal source



LiF superheated vapor injection - low temperature materials configuration

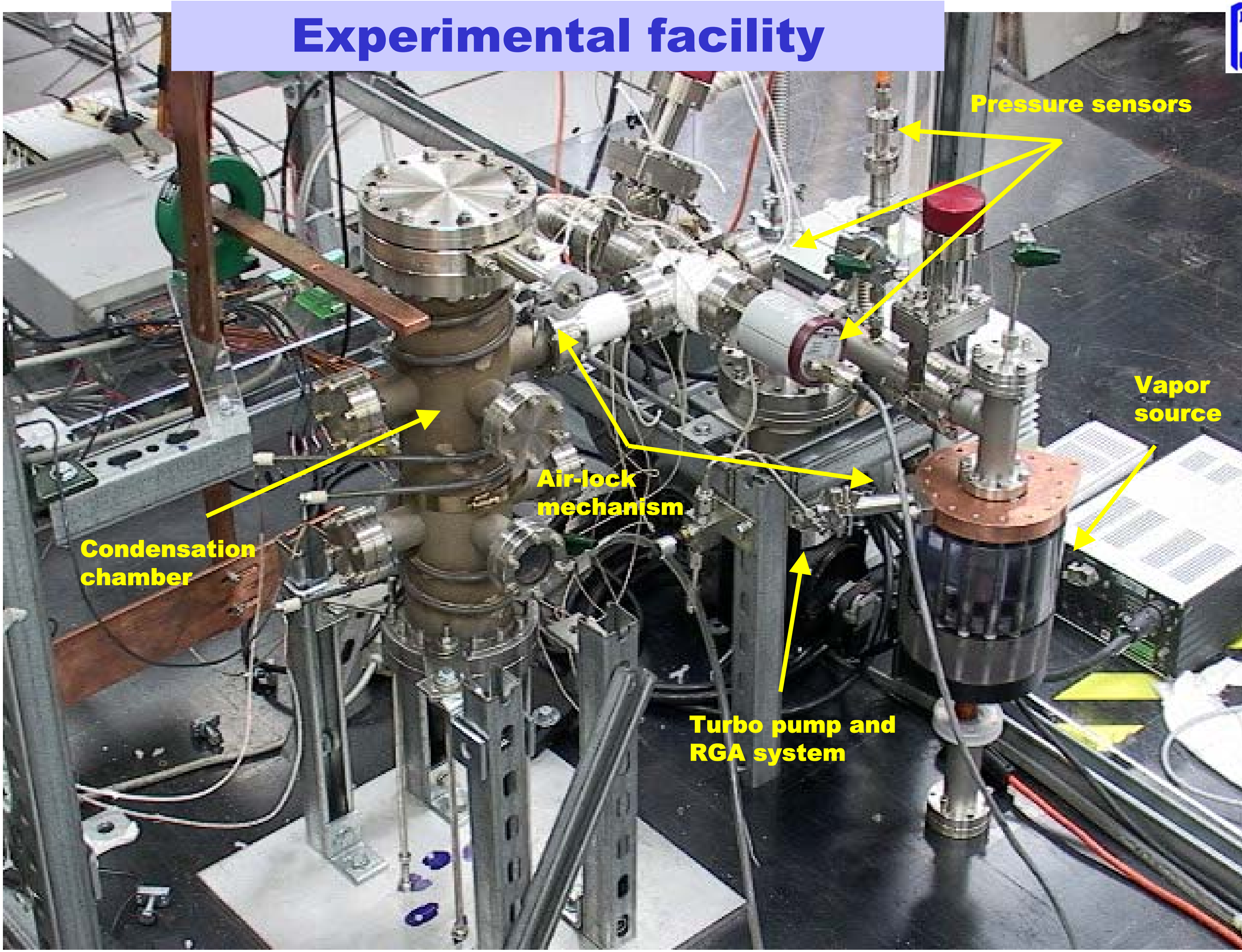


Sleeve (LiF) configuration

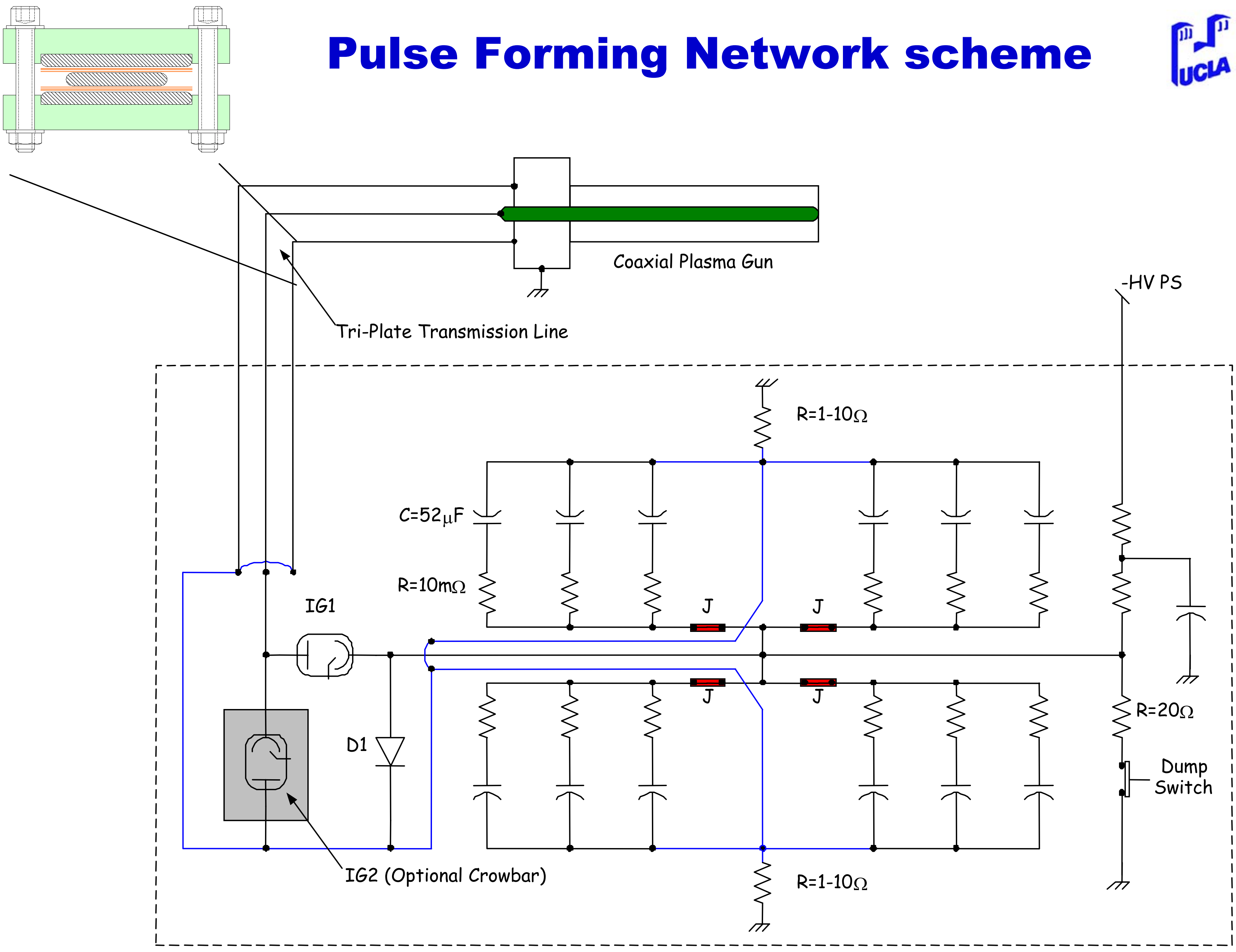
Chamber upper flange

Connection to return leg and vacuum sealing

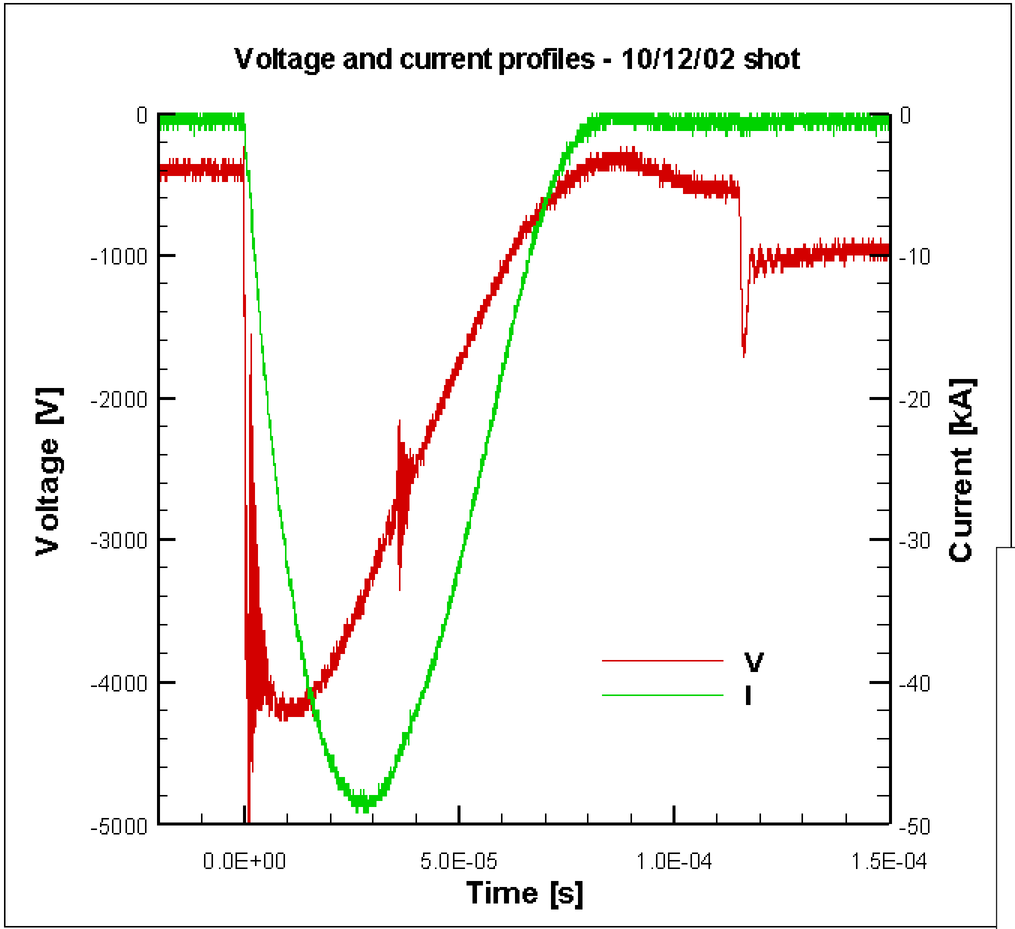
Experimental facility



Pulse Forming Network scheme

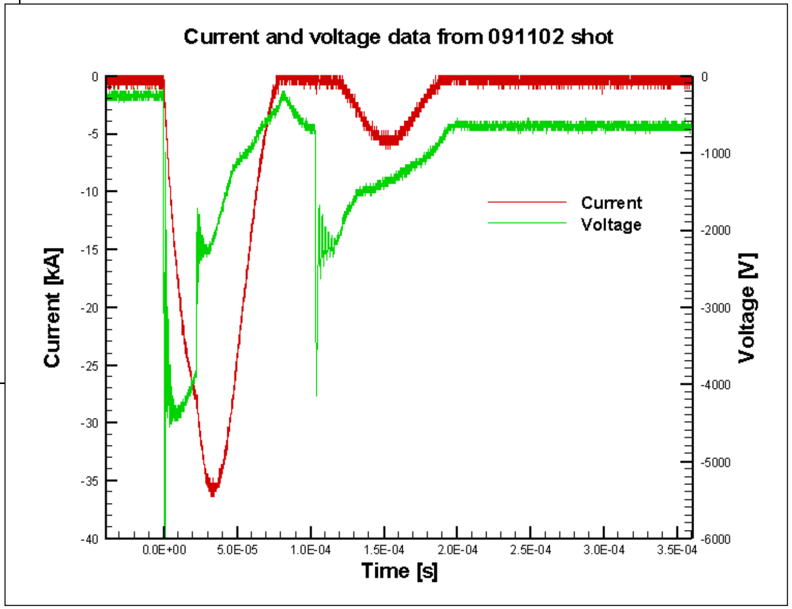


Measured discharge parameters



Triggering wire eliminated the possibility of secondary discharges

Enhanced reliability of the source is key for flibe

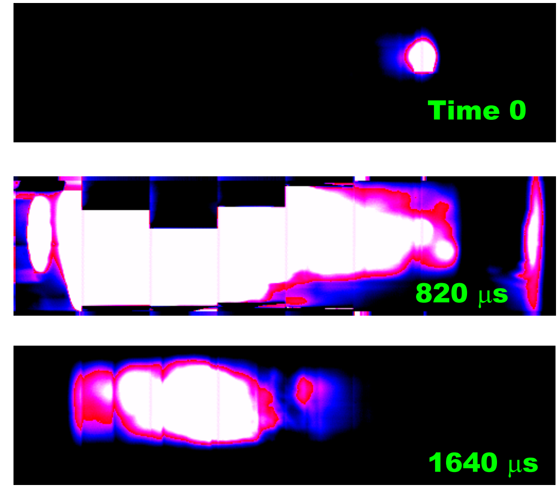


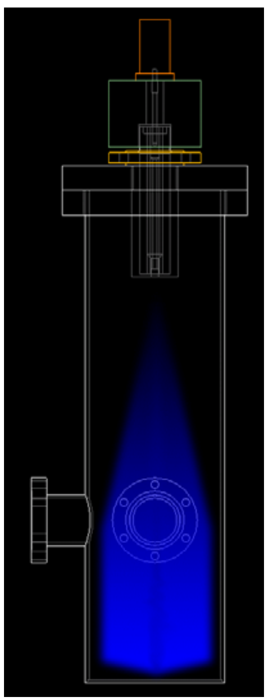
Measured electrical parameters of typical teflon shots during facility testing - power injected in the superheated vapor is V x I

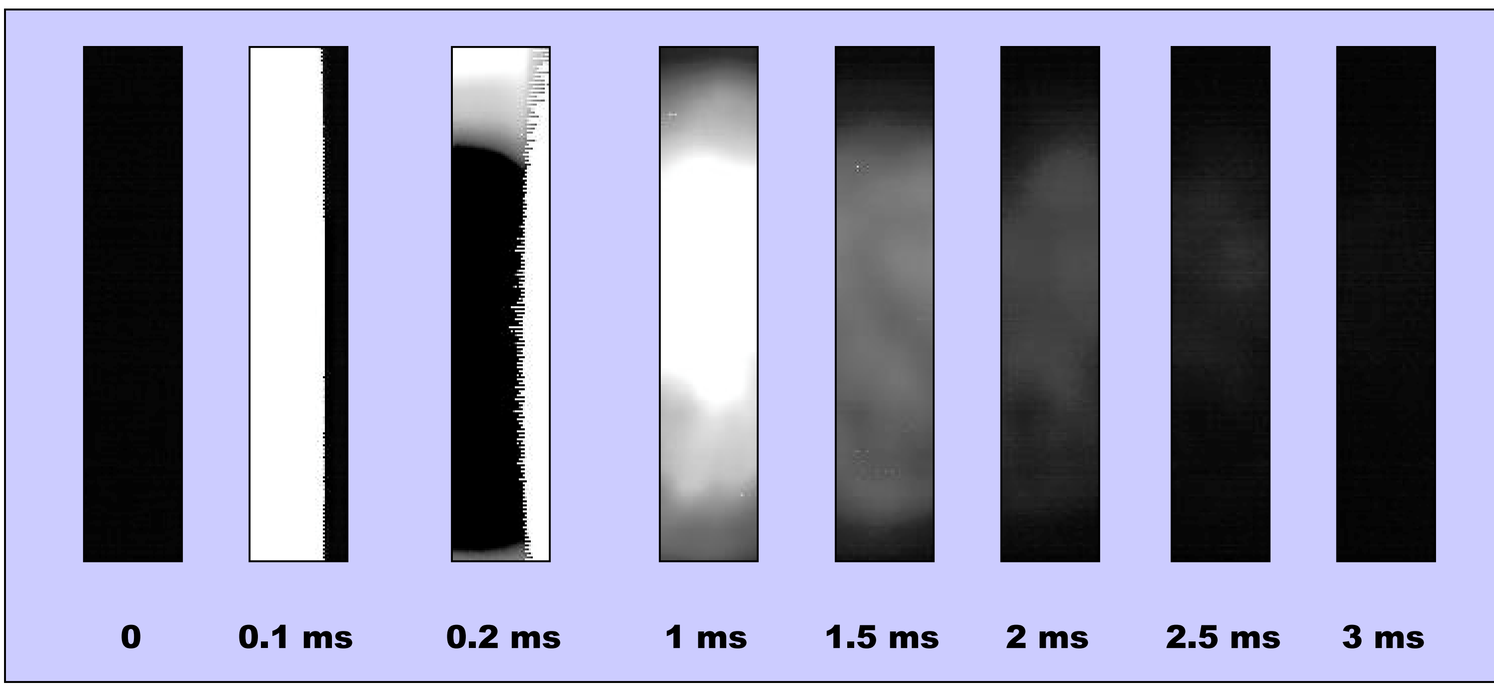
Light emission characterization

Lexan shots

Frame sequences recorded with high speed camera - 10,000 frames per second and shutter speed of 100 ms

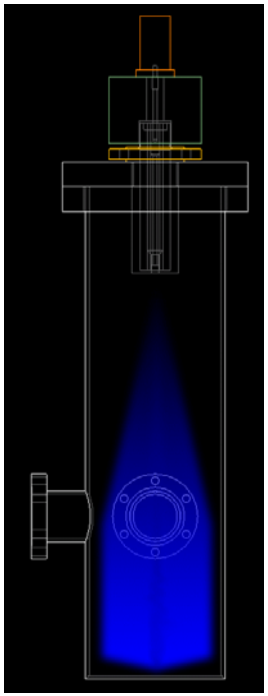


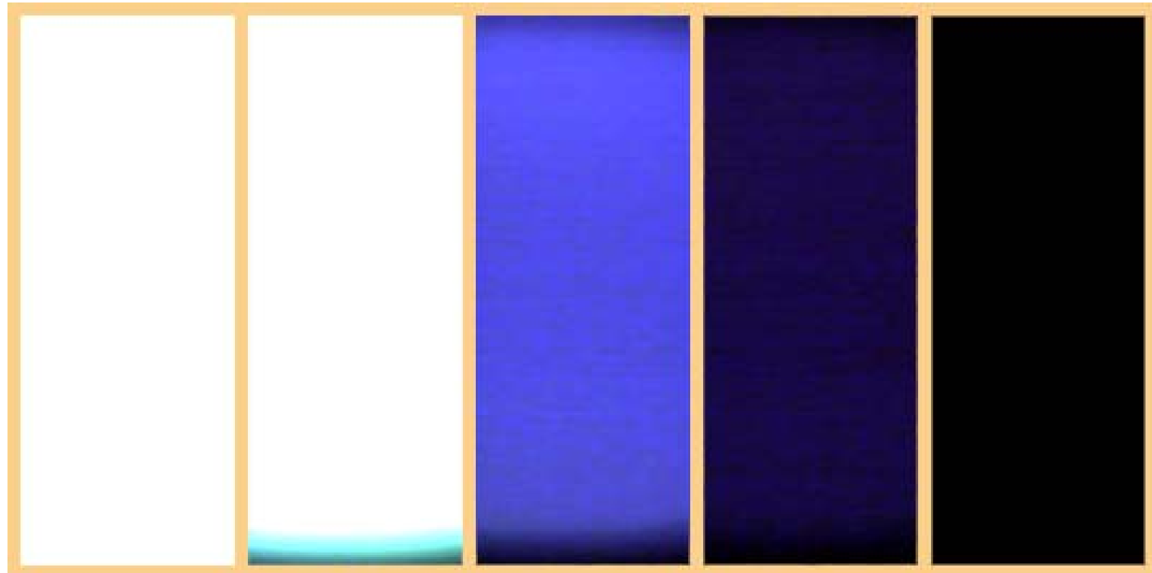




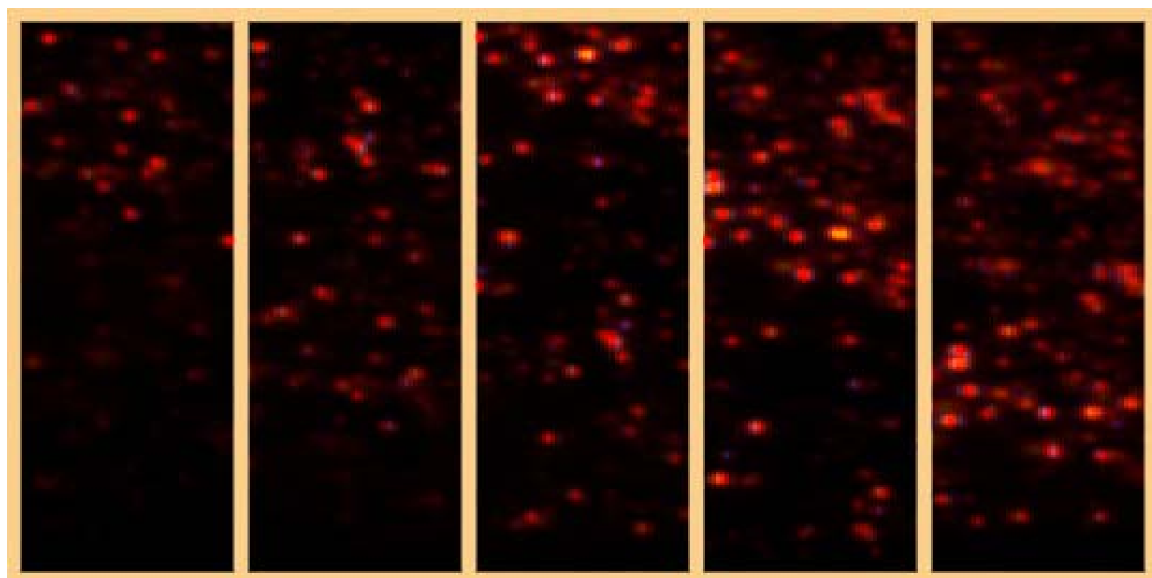
Light emission characterization

Metal vapors characterization: tin shot





0.0001 0.0002 0.0003 0.0004 0.0005



0.0030 0.0032 0.0034 0.0036 0.0038

With metal sleeves formation of a liquid metal layer occurs over the ablated surface

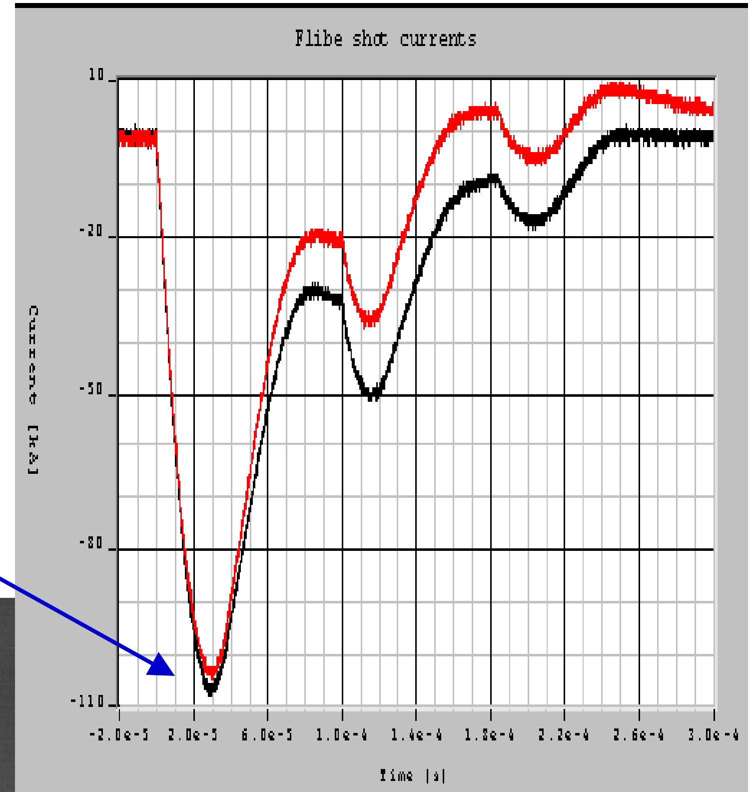
The liquid falls by gravity in the chamber - droplet size too large to be homogeneous volumetric condensation

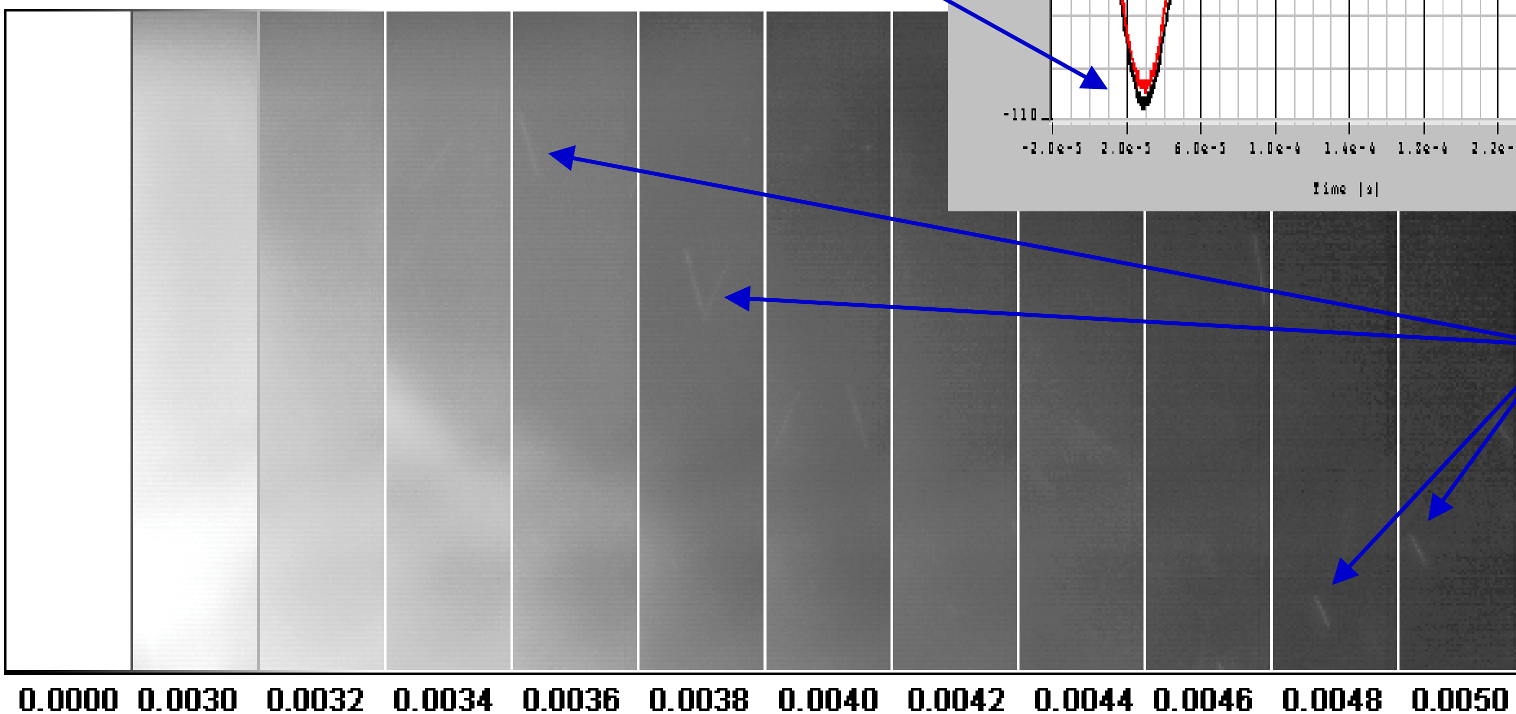
Light emission characterization

High energy flibe shot

Current peak 110 kA

Discharge completed 300 μs after trigger





Injected debris

Emission spectroscopy

Objective:

Locally map the partial density of neutral Li, LiF and Be, BeF_2 as a function of time over the whole chamber clearing period

Neutral species temperature can also be inferred with additional development

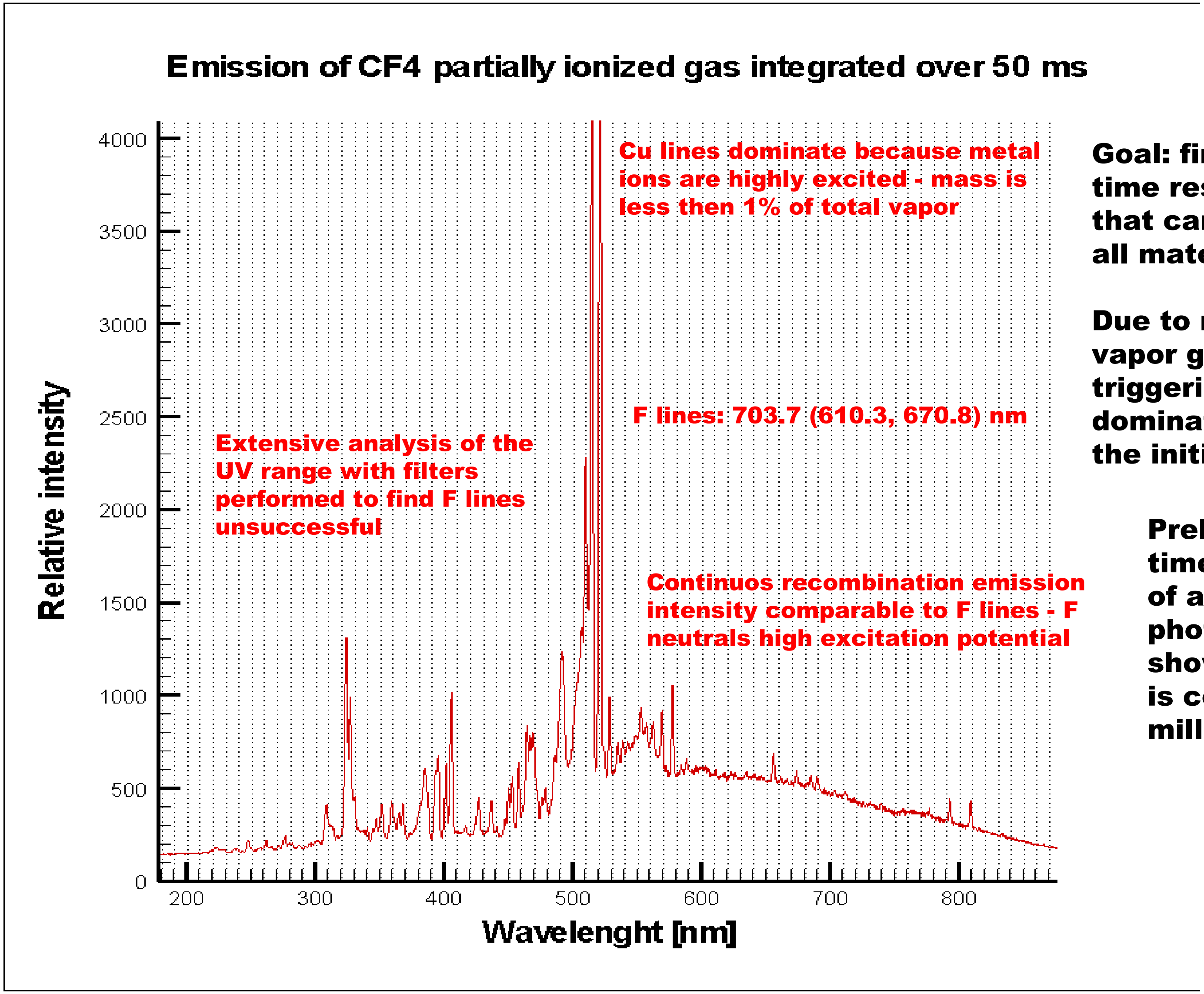
- **Injected vapor spontaneous emission is short lived, and superheated vapor properties are far from optimal for spectroscopy measurements - high density and low temperature**

- **An high-voltage arc is used to re-excite the condensing vapor and analyze radiation emission at different times - excited vapor can reach up to 30 eV typically and densities will drop as the vapor condenses**

- **The arc will excite the vapor locally, allowing to analyze the different properties of vapor in the volume bulk or near a condensing surface**

- **The high-voltage arc is under testing in steady state conditions with LiF vapors**

Emission spectroscopy - CF_2 shot

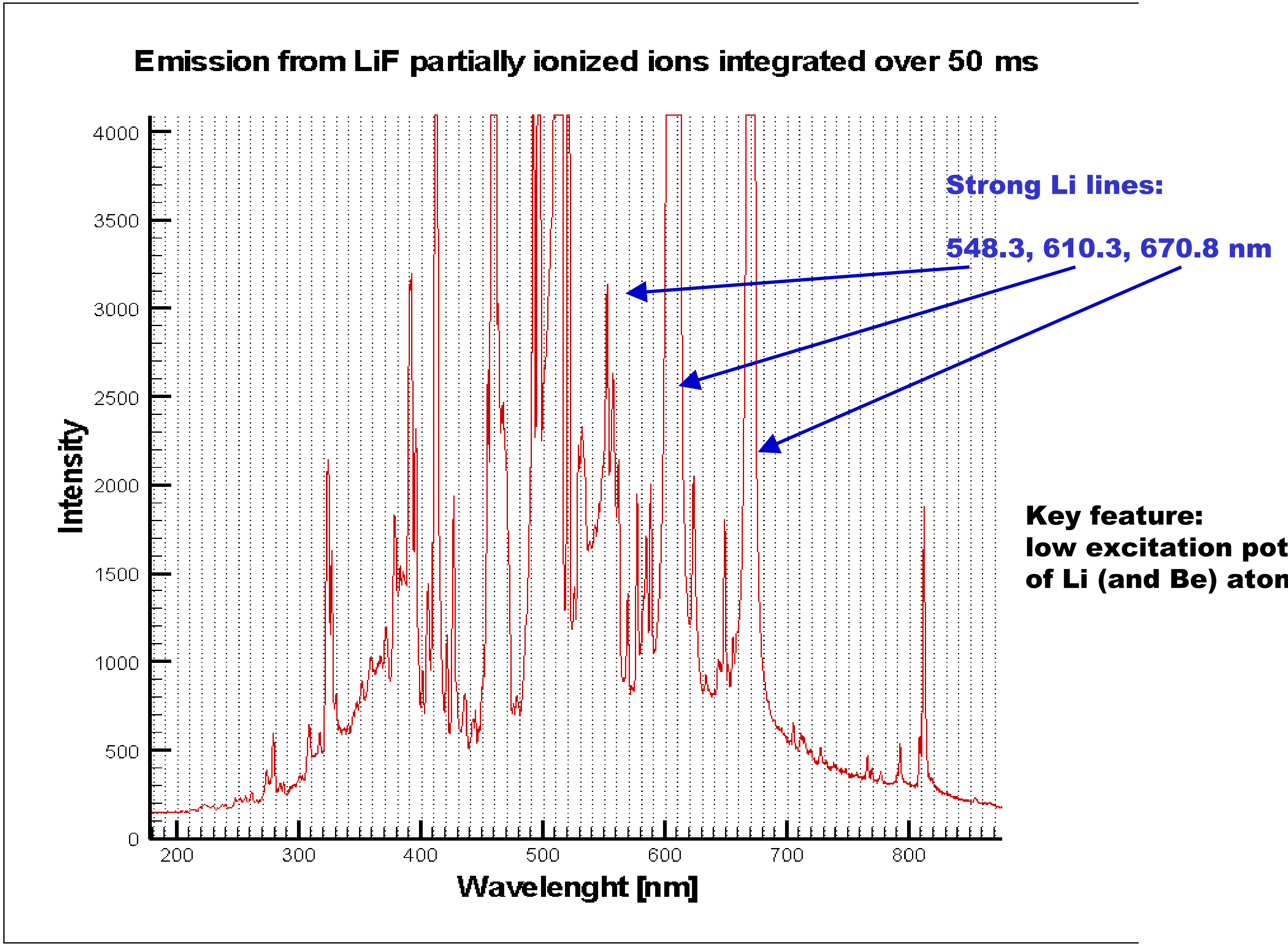


Goal: find suitable lines for time resolved spectroscopy that can be analyzed with all materials of interest (F)

Due to non-uniform excited vapor generated with the triggering wire, Cu lines dominate the spectrum in the initial phase

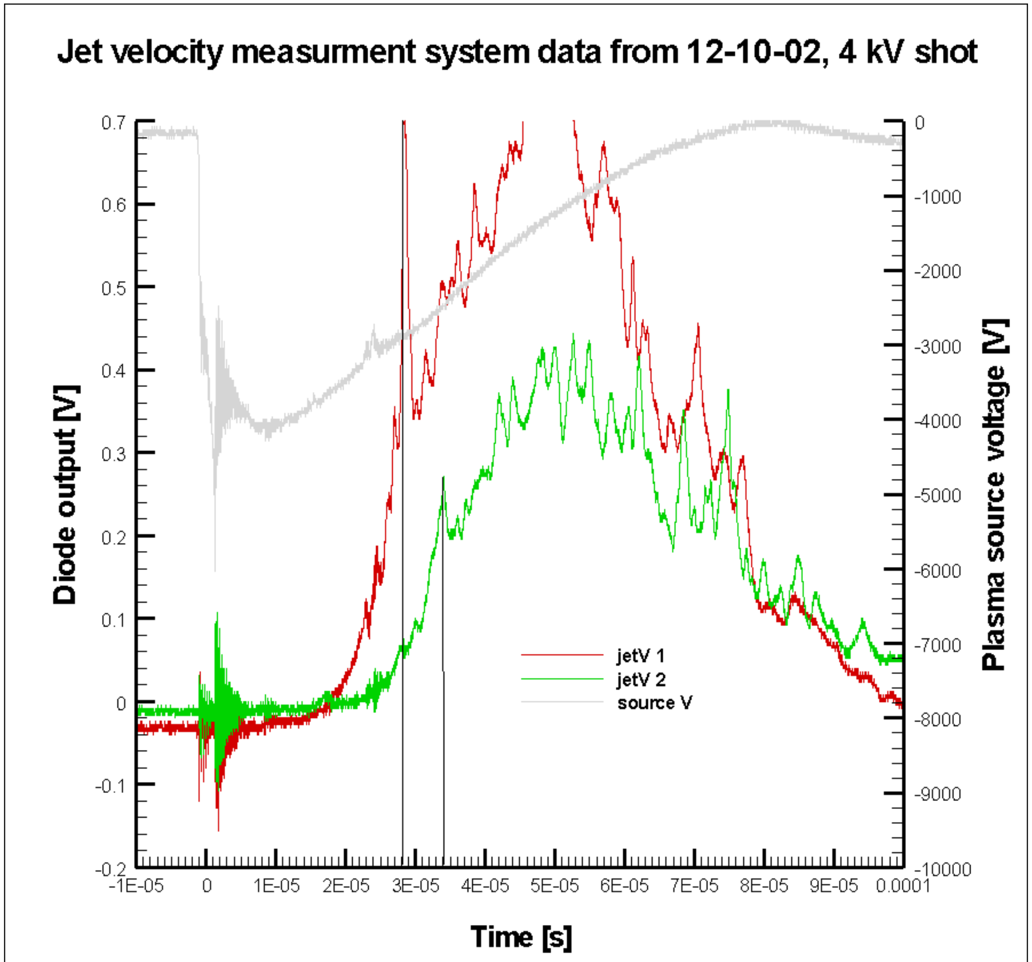
Preliminary results of time resolved analysis of a Cu line with a photon multiplier showed metal emission is confined in the first millisecond

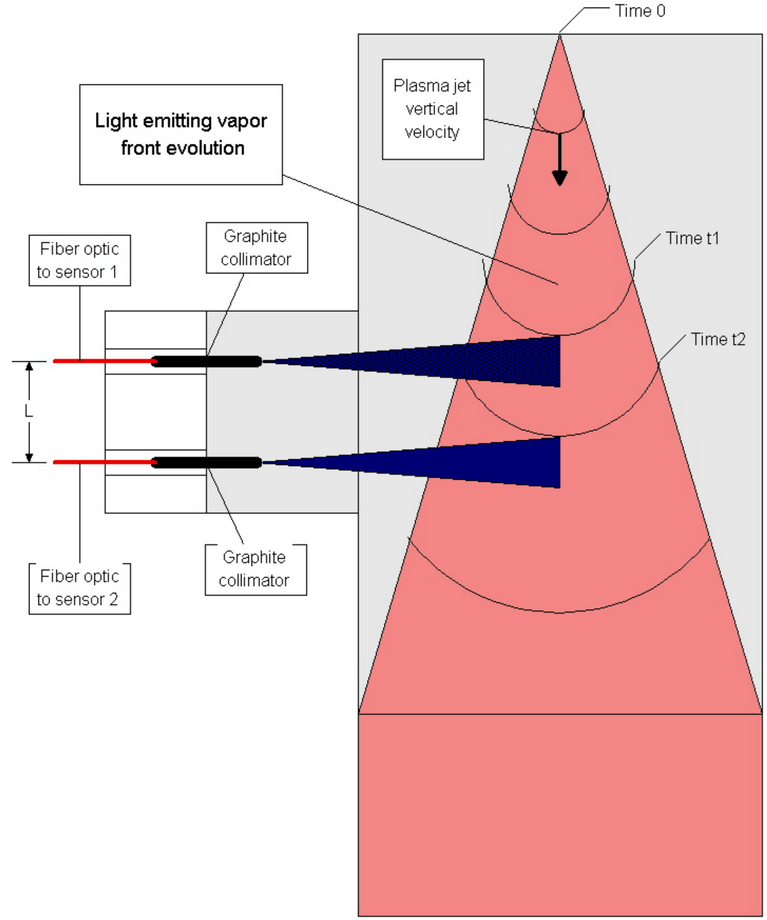
Emission spectroscopy - LiF shot



Key feature:
low excitation potential of Li (and Be) atoms

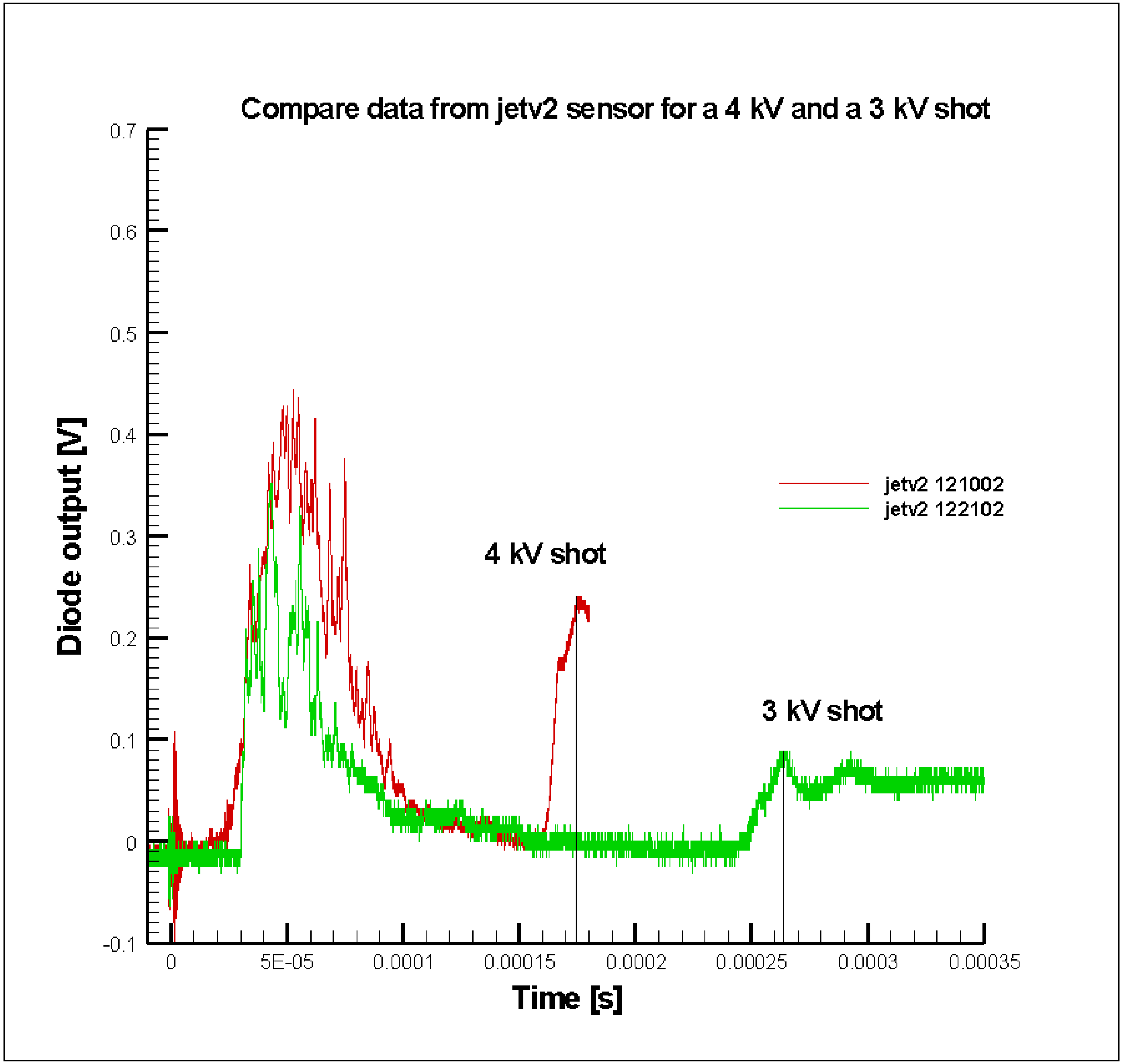
Jet velocity optical measurement system





Diode axis separation:
7.62 cm
Peak time delay:
6 microseconds
Estimated initial vapor velocity:
12700 m/s

Jet velocity optical measurement system



Sensor closer to center of chamber sees a second peak in the light, about 2ms after triggering

Peak due to first reflection of the vapor jet at the chamber bottom

Vapor cools and expands in the chamber, emitting front does not reach the upper sensor

Estimated average velocity of vapor in the chamber after first reflection:
320 m/s - 4 kV
210 m/s - 3 kV

Experimental plan

Reduce to minimum traces of non condensable gases in the chamber - extend pressure history to mTorr range:

- **new, clean chamber for LiF shots - no C contamination**
- **add air-lock system in the plasma source to avoid open chamber to air each shot to change triggering wire**

Measure LiF chamber clearing rates and characterize amount and composition of non condensable gas to define accurate simulations conditions for Tsunami / condensation code

Complete development of emission spectroscopy system - measure density of Li atoms and LiF molecules at different times in the bulk volume and near a condensing surface - analyze data and provide conditions for accurate simulations with Tsunami / condensation code

Insert flibe disks in the source - measure the effect of the added presence of BeF_2 in the vapor

The End