H^- Ion Source for Project X

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Project X Collaboration Meeting

H^- Ion Source Candidates for Project X

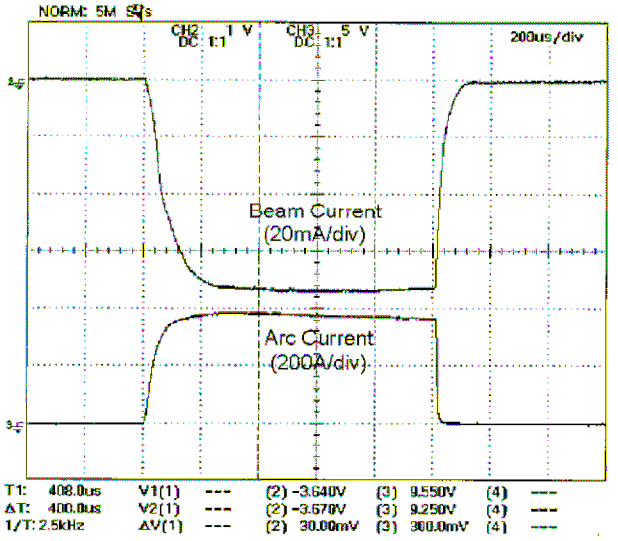
- **Specification of Project X H^- ion source**
  - cw operation, 10 mA, normalized rms emittance < 0.2 π mm mrad
  - Pulsed H^- beam at 10Hz, with 5 ms pulse width, 0.5 ms pulse ramping up and down, with variable beam intensities of adjacent pulses
- **Filament-discharge H^- ion source as baseline**
  - No Cs
  - cw operation, proven technology
  - Limitations
- **Advanced RF-driven H^- ion source**
  - Longer lifetime (> 500 hr)
  - Better emittance
  - Flexible pulsing structure

Filament-discharge H^- Ion Source

- Filament driven H^- source provides a rapid-entry, low risk solution
  - Having this source can expedite R&D of LEBT
  - Emittance is marginal
    - normalized 4rms emittance ~ 0.8 π mm mrad
  - cw 10 mA
  - Limited lifetime
    (~ 350 hr with reduced aperture)

- More optimization opportunities
  - Pulsing capability needs to be tested
  - Extraction system optimization

< 0.2 ms pulse ramping time

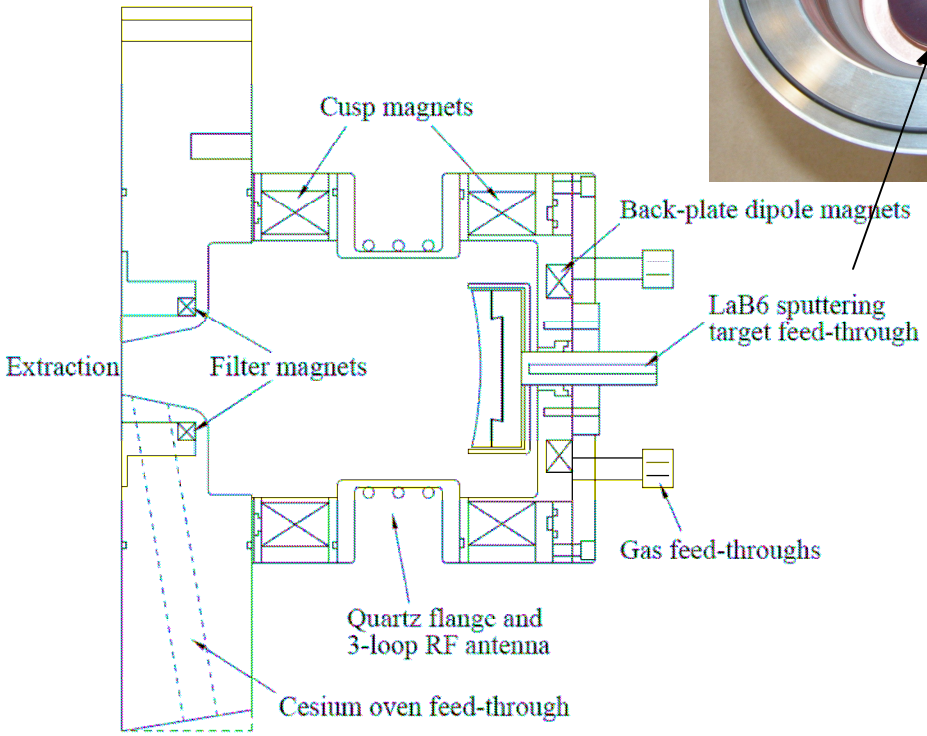


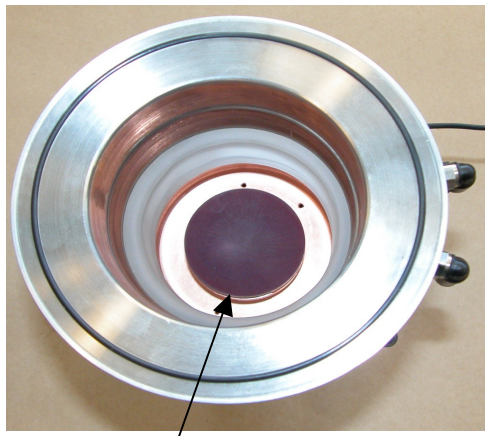
Oguri et al, Rev. Sci. Instru. **73**, 1021(2002).

History of LBNL H^- Ion Source Development

- LBNL pioneered development of both filament and RF-driven H^- ion source
  - 1983, **filament**, no Cs, pulsed 38mA/cm^2, @ discharge power of 90V, 350A.
    K. N. Leung et al, Rev. Sci. Instru. 54, 56 (1983)
  - 1988, **filament**, no Cs, pulsed 250mA/cm^2, @ discharge power of 150V, 450A.
    K. N. Leung et al, Rev. Sci. Instru. 59, 453 (1988)
  - 1991, **RF** internal antenna, stainless steel collar, pulsed 200mA/cm^2, @ power of 50 kW.
    K. N. Leung et al, Rev. Sci. Instru. 62, 100 (1991)
  - 1993, **RF** internal antenna, w/ Cs, long pulse (50 ms), 2.76 mA/cm^2/kW.
    J. W. Kwan et al, PAC 1993 proceeding, p. 3169
  - 1993, **RF** internal antenna, Cs collar, pulsed 80 mA @ power of 40 kW.
    K. N. Leung et al, Rev. Sci. Instru. 64, 970 (1993)
  - 1998, **RF** internal antenna, Cs collar, pulsed 35 mA @ power of 40 kW.
    M. A. Leitner et al, Rev. Sci. Instru. 69, 962 (1998)
  - 2002, **RF** internal antenna, Cs collar, pulsed up to 50 mA @ power of 40 kW.
    R. Thomae et al, Rev. Sci. Instru. 73, 2016 (2002)
  - 2007, **RF** external antenna, w/o and w/ Cs, **cw operation**, up to 10 mA/cm^2 @ power of 1 kW.
    T. Kalvas et al, CP925, Production and Neutralization of Negative Ions and Beams,11th International Symposium, 2007.

External Antenna RF H- source (configuration)

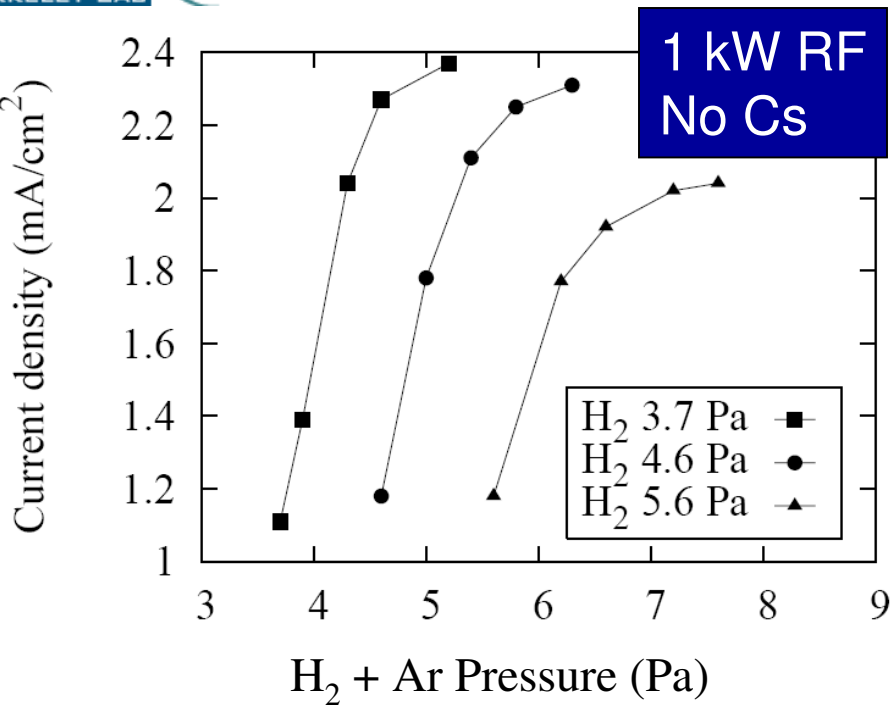


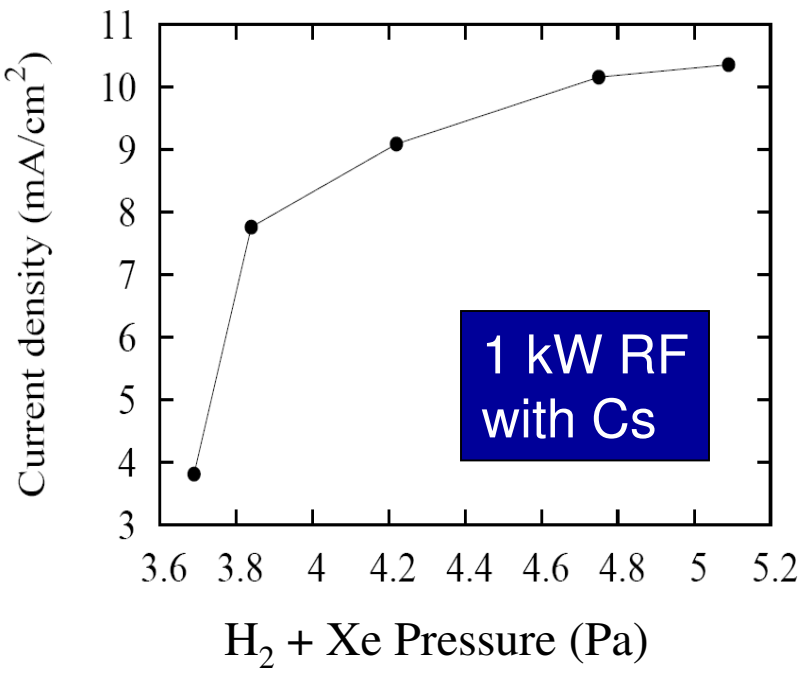


96 mm long, 75mm diameter

T. Kalvas et al, "Multicusp ion source with external RF antenna for production of H^- ions", CP925, *Production and Neutralization of Negative Ions and Beams,11th International Symposium,* American Institute of Physics, 2007.

External Antenna RF H- source (cw operation)





- **Small extraction (Φ2mm) aperture and source is not fully optimized yet.**
- **Demonstrated cw H- production in 13.56MHz RF H- ion source**
  - 1 kW RF power, no Cs, Ar gas mixing, 2.4 mA/cm^2
  - 1 kW RF power, with Cs, 4.4 mA/cm^2
  - 1 kW RF power, with Cs, Xe gas mixing, 10.3 mA/cm^2 (comparable to filament source)

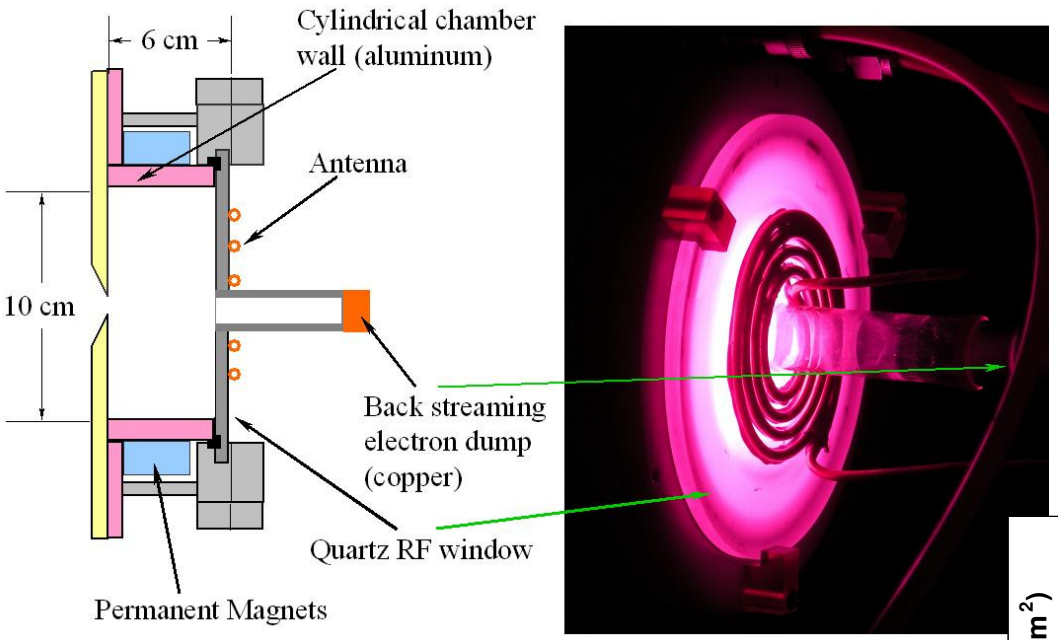
T. Kalvas et al, "Multicusp ion source with external RF antenna for production of H- ions", CP925, *Production and Neutralization of Negative Ions and Beams,11* International Symposium,* edited by M. P. Stockli, American Institute of Physics, 2007.

Proposed R&D on cw RF-driven H^- Ion Source

- LBNL will start from the external antenna cw 13.56MHz RF-driven ion sources developed in the past
  - RF ion source technology for both proton and H^- ion source
  - Ion source hardware available in house, need modification and assembly, testing, and further optimization

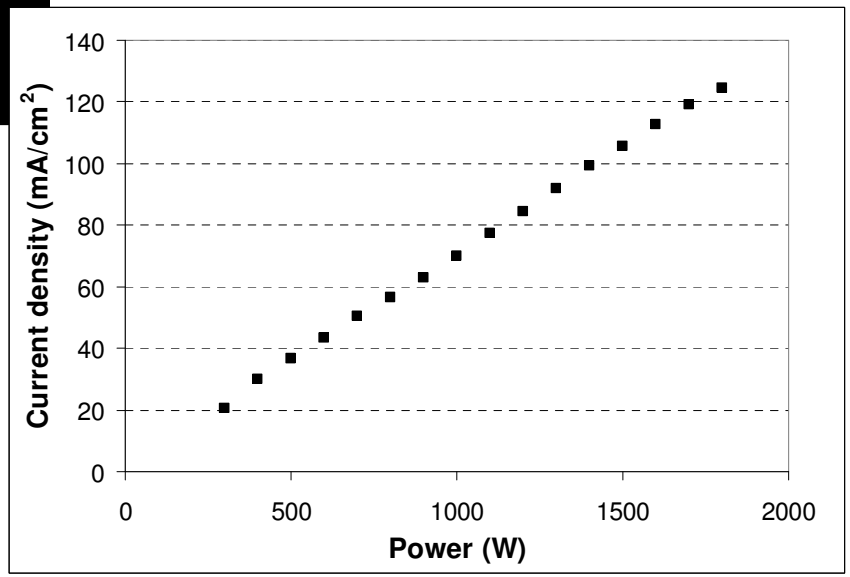
- Investigate external antenna cw RF-driven H^- ion source for higher brightness and longer lifetime
  - This is the trend in the field
  - Improve power efficiency in the driver region
  - Minimize H^- destruction process by lowering the electron temperature in the extraction region with optimized filter magnet or/and biased mesh grid
  - Improve hydrogen dissociation process and reduce e/I^- ratio by optimizing wall material and surface catalytic process around collar region

RF (13.56MHz) H^+ source with external antenna

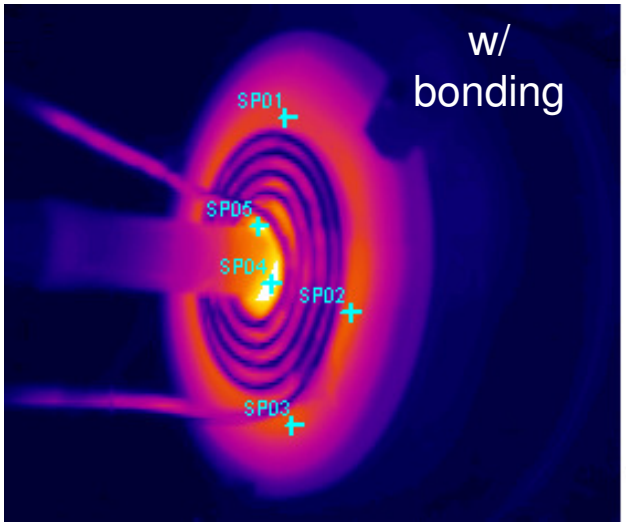


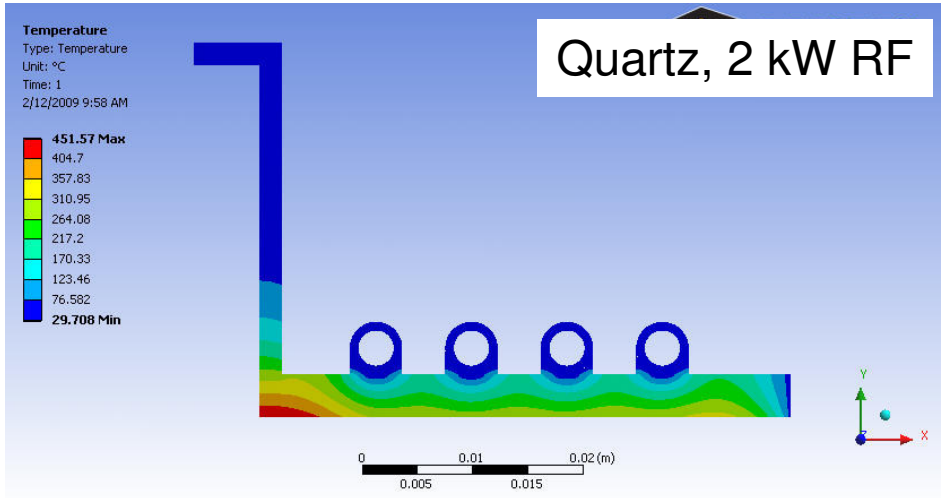
Q. Ji and J. W. Kwan, "RF-driven proton source with a back-streaming electron dump", Rev. Sci. Instrum. 81, 02B312 (2010).

Characterized power efficiency at driver region

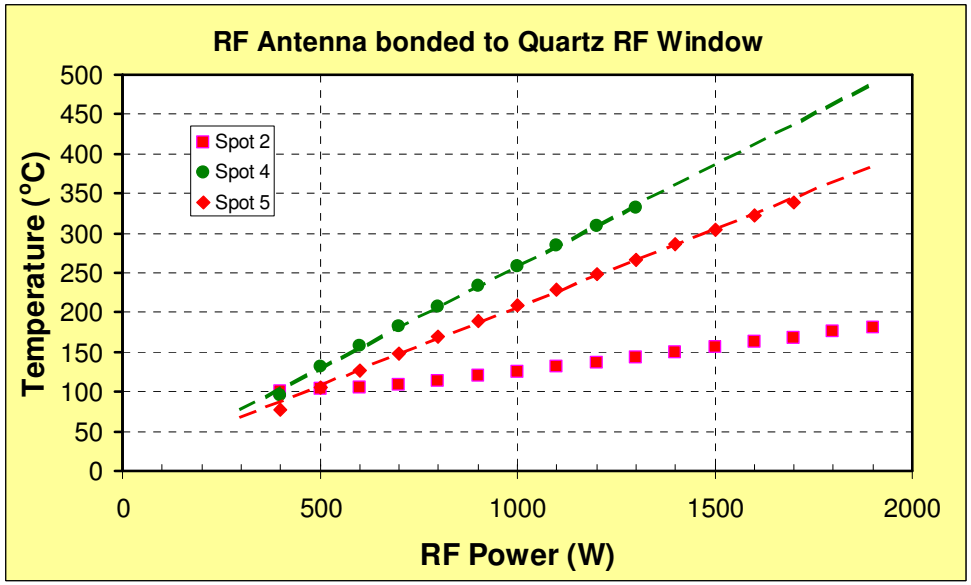


Key Challenge: RF window Engineering for cw High Power Operation





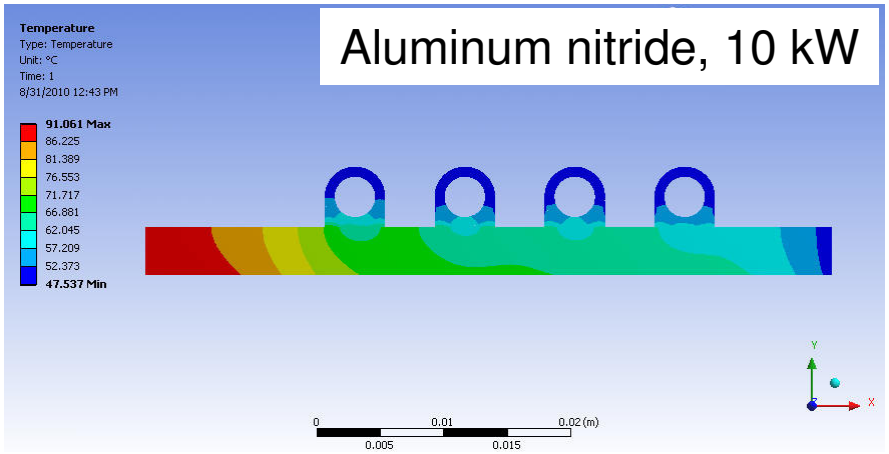
Q. Ji and J. W. Kwan, "RF-driven proton source with a back-streaming electron dump", Rev. Sci. Instrum. 81, 02B312 (2010).



Aluminum Nitride as RF Window for cw Operation

temp @ 400 K	Thermal conductivity (W/m/K)
Quartz	1.4 (1)
Aluminum nitride	180 (2)

Ref. (1) Abdulagatov et al, J. Phys. Chem. Solids, 61, 779(2000).
(2) Slack et al, J. Phys. Chem. Solids, 48, 641(1987).



Simulation shows that aluminum nitride as RF window can sustain 10 kW of cw RF power with proper cooling.
⇒ Meet specs for 10 mA H^- at current efficiency of 1 mA/kW.

Summary

- Filament driven H^- source provides a rapid-entry, low risk solution; also needs R&D.
- Having a filament driven H^- source will expedite the R&D of LEBT.
- LBNL has strong institutional knowledge and expertise in H^- ion source research and development.
- LBNL has a lot of experience in RF sources operating at 13.56 MHz for both proton and H^- production.
- We propose an R&D effort on a next generation, cw/pulse operation, RF H^- ion source with external antenna.