Experimental Results, Status and Prospects of a Helicon-driven, Converter-type H^- Ion Source

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Performance Parameters

For LANSCE Helicon-based Ion Source

Future performance goals for LANSCE H^- source

- **28 mA H^- beam current**
  - 0.15 π mm mrad normalized 1-σ emittance
- **10.5% duty factor**
  - 120 Hz repetition rate
  - 865 μs pulse length
- **4 weeks operation between services**

Current performance of filament-driven source

- **16.5 mA H^- beam current**
  - 0.15 π mm mrad norm., 1-σ emittance
- **5.3% duty factor**
  - 60 Hz repetition rate
  - 865 μs pulse length
- **4-5 weeks operation between services**

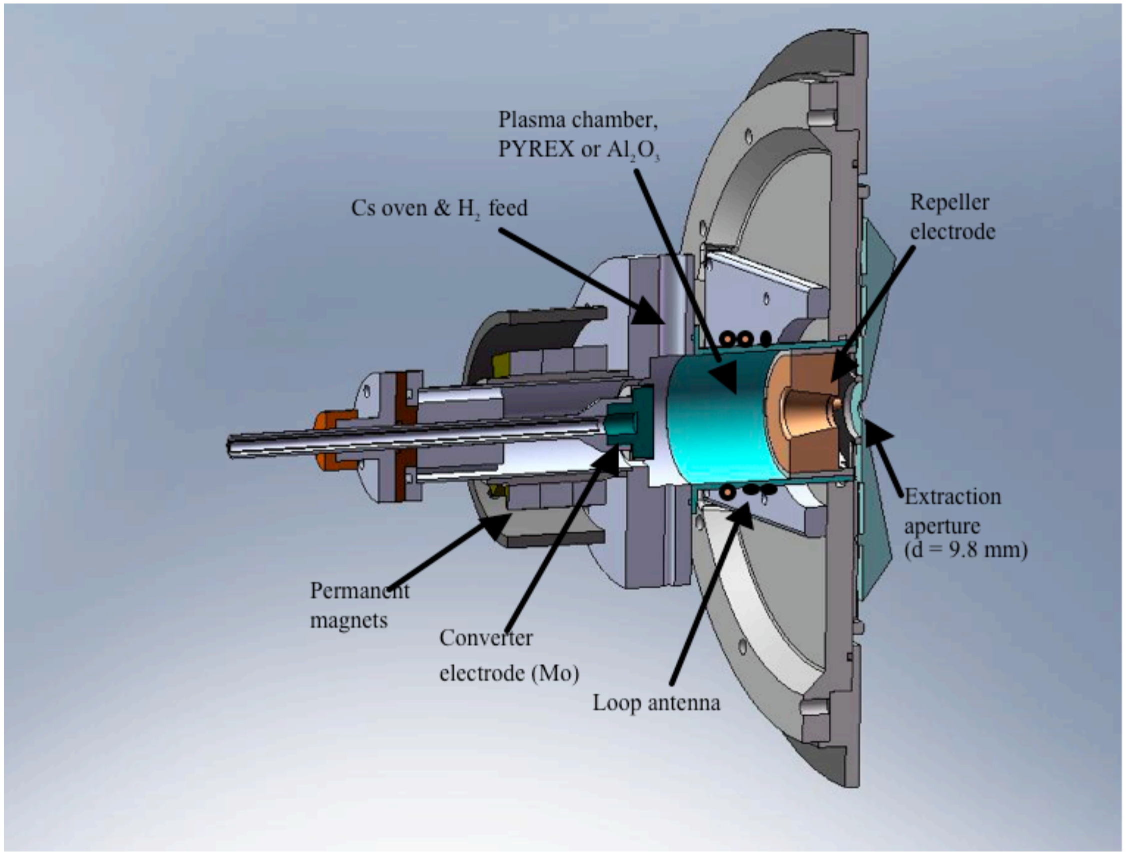
Helicon approach

- **Helicon generators were developed for space propulsion systems**
  - Wide-spread use in industrial applications
  - Resident expertise at ORNL and LANL
  - Proof-of-principle helicon device tested at LANL before converter-helicon work
- **Plasma density ≥ 1 x 10^{13} cm^{-3}**
  - With very high power efficiency
- **External antenna**
  - Quartz or alumina wall of discharge vessel acts as insulator
  - Promise of "unlimited lifetime"
  - **Original double-helical antenna shape only needed for m=1 mode**
- **Helicon mechanism requires axial magnetic field**
  - Moderate field strength
  - Created by permanent magnets
    - 100 G at location of antenna for m=0 mode

LANL Converter Helicon

As H^- ion source

- **Combined with standard LANSCE converter source**
  - Suggested by R. Welton, ORNL
  - Helicon plasma generator replacing filaments and discharge power



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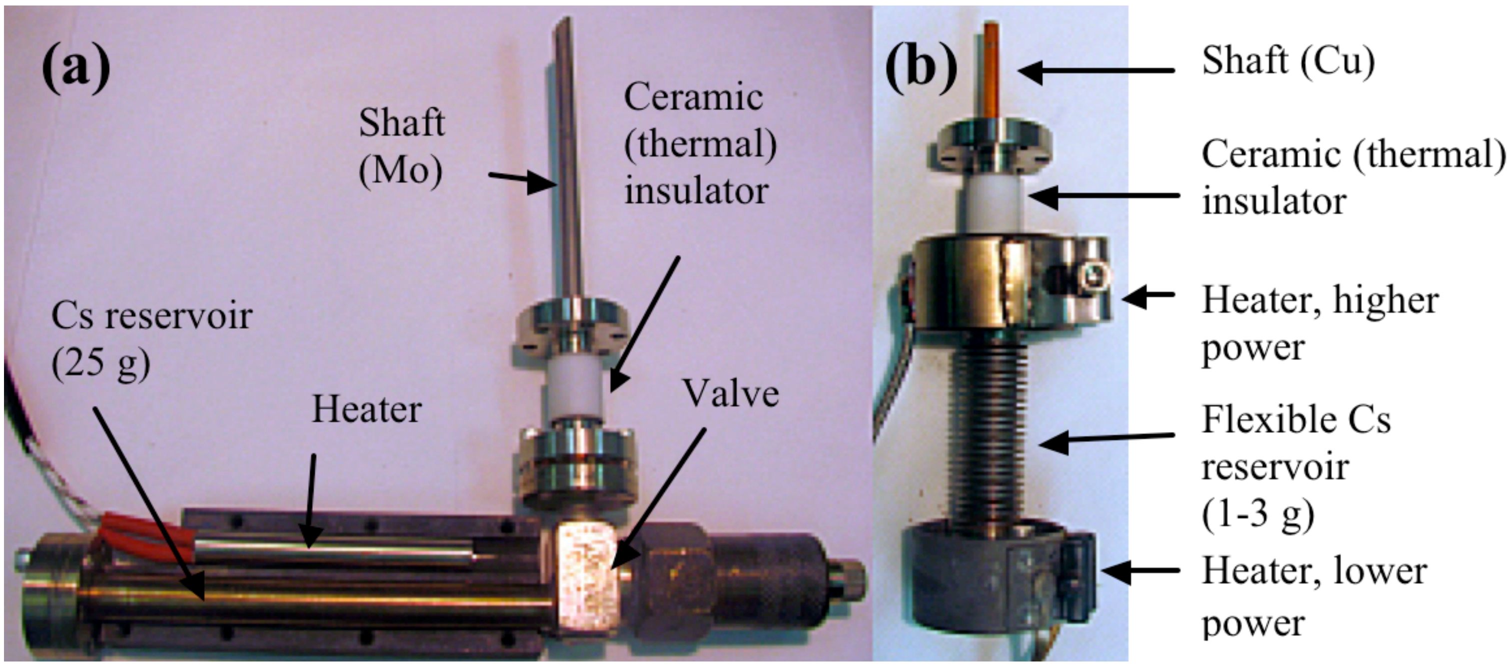
LANSCE Converter-Helicon Parameters

- **Axial magnetic field created by permanent magnets**
  - 100 G at location of antenna (m = 0 mode of operation)
  - Permanent magnet ring in repeller electrode adding to this field
    - Removes most electrons from H^- beam
    - **Creates 200-G field hump near outlet aperture**
- **13.56 MHz rf frequency**
- **Capacitive impedance-matching circuit**
- **1 – 20% reflected power with stable discharge**
- **250 - 350 V converter bias with respect to outlet flange**
- **9.8-mm diameter outlet aperture**
- **Newly designed cesium oven**
  - Transfer tube hotter than oven itself
  - Prevents re-condensation and subsequent cesium bursts
    - Coating of chamber walls by cesium would lead to high reflected rf power

New Cesium Oven Layout



Standard oven **New oven**

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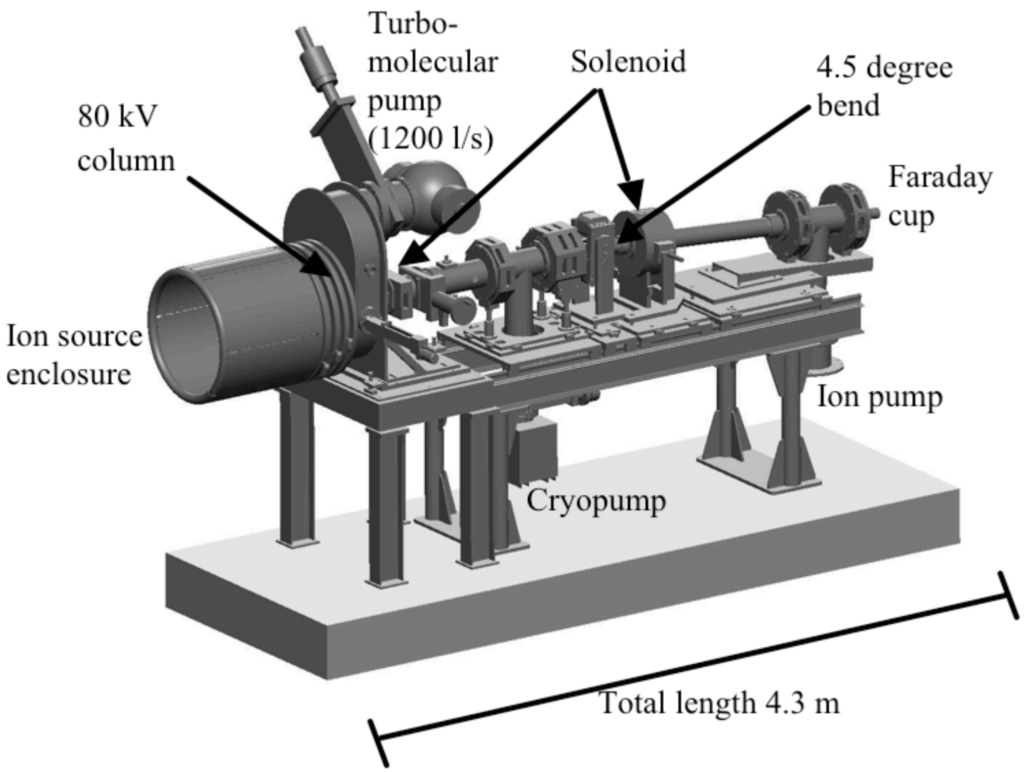
Test Stand Layout

- **80-kV extraction**
- **2-solenoid LEBT**
- **2 emittance stations**



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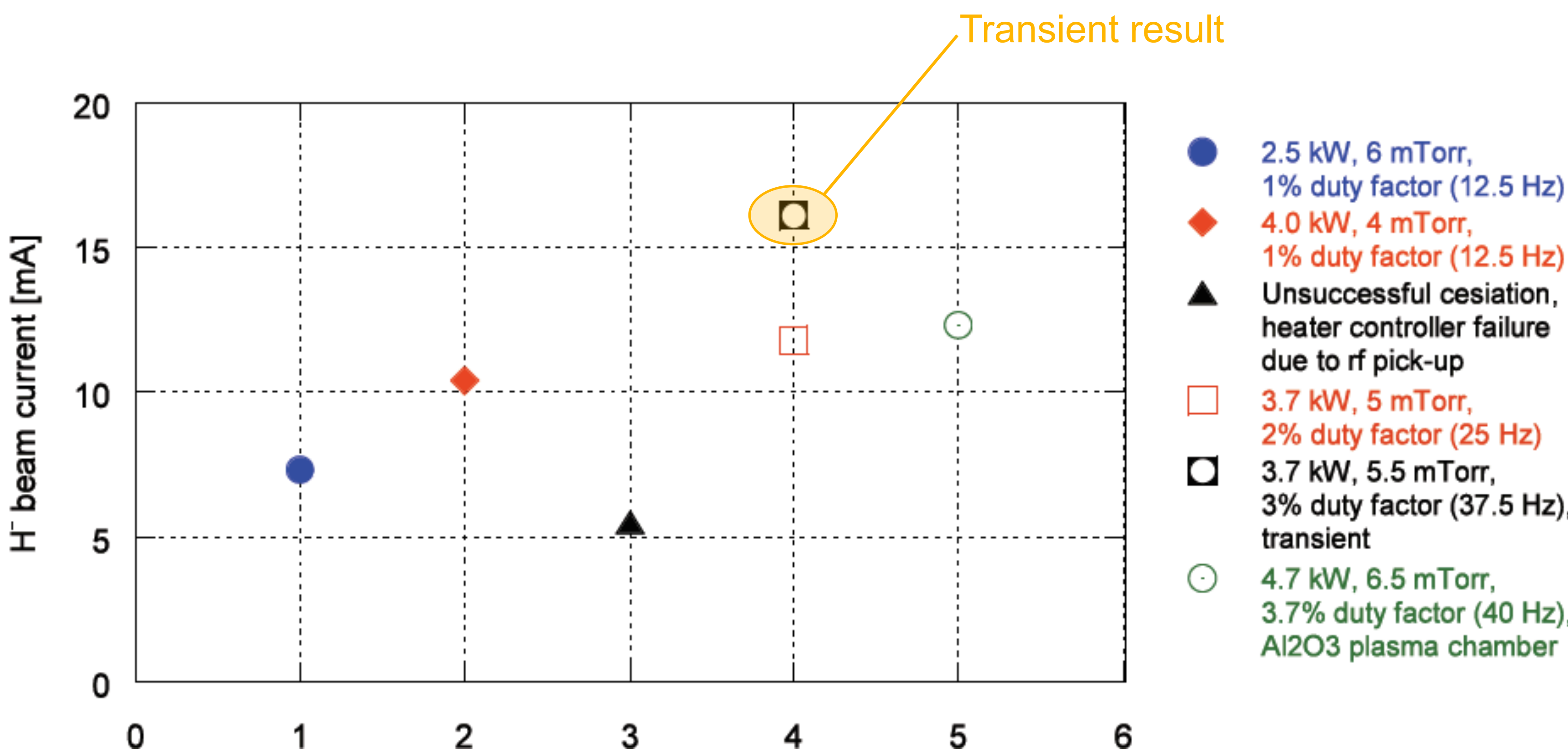
Test Results



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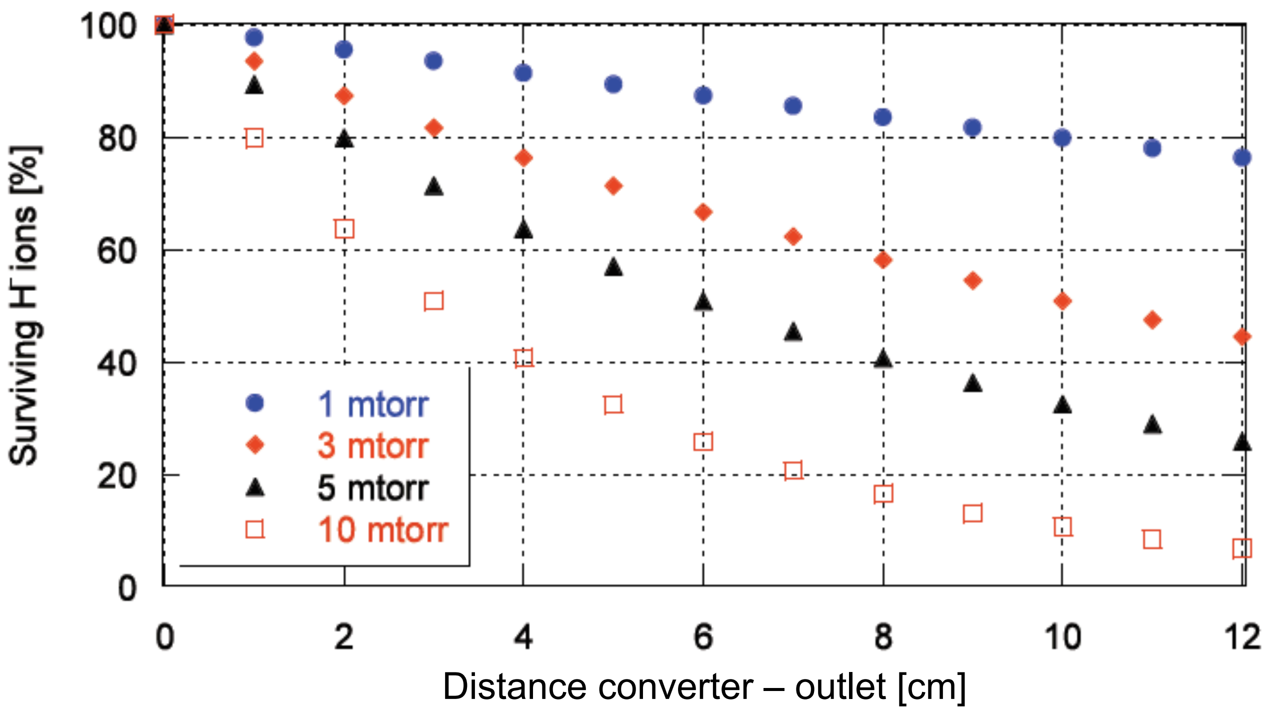
Observed Trends

- **H^- beam current increases with increasing power**
  - Jump at 1 – 1.8 kW (onset of m=0 helicon mode)
  - Power increase requires cesium-flow increase
    - Compensate for higher ablation rate
  - Power increase requires gas pressure increase to control reflected power
- **H^- beam current increases with decreasing gas pressure for constant rf power**
  - Reduction of H^- stripping losses in discharge plasma
  - Cesium flow has to be reduced as well
  - 7 - 8 mTorr is lower limit (excessive ignition delay)
  - No significant gas starvation observed
    - Less than 10% fading over 865 μs pulse length
- **High cesium flow facilitates discharge ignition**
  - Affects matcher settings
    - Increases reflected power
    - Not optimal for beam-current output

Outlook (1)

- **Minimum gas-pressure limit for ignition is most severe restriction for raising beam current**
  - Stripping losses for generated H^- ions are fairly high
    - Could reduce distance of converter from outlet



Model Calculation

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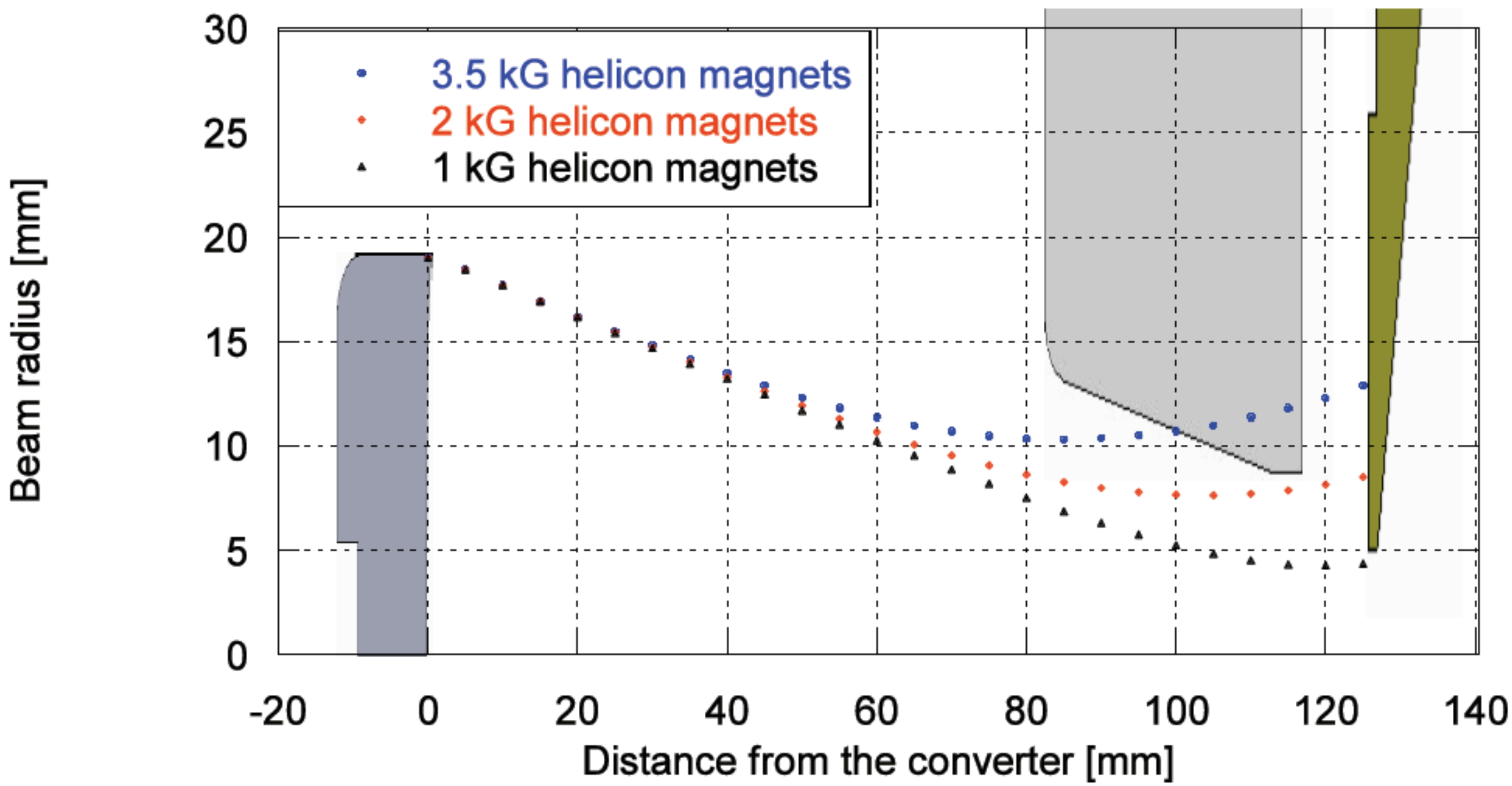
Outlook (2)

- **Reduction of gas pressure is next goal**
- **Avoid gas starvation during pulses**
  - Larger vessel (upstream of converter)
  - Pulsed gas feed
    - Would require much longer rf pulses
      - Have to let pressure decay from initial value
    - Developed and briefly tested 150-μs gas injector at 60 – 120 Hz
- **Facilitate pulse ignition by spark source in gas-feed line**
  - Tesla coil igniting neutral gas at fairly high pressure
  - Successful preliminary tests with pure hydrogen
    - **Reduced pressure in source from 8 to 4 mTorr or less**
- **Optimize magnetic field near repeller**
  - Conflicting trends when lowering fields
    - Better ion transport
    - Lower plasma density

Outlook (3)

- **Simulated effect of repeller magnetic field on beam footprint**
  - 3.5 kG currently used, lower field improves transport
  - But: lower field appears to reduce plasma density



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Outlook (4)

- **Encouraging preliminary test results**
  - 1.5x current increase would match standard source performance
- **Several options for improvements identified**
- **No emittance results obtained**
  - Expecting similar values as with standard source
    - 0. 15 π mm mrad 1-σ normalized
- **Duty factor lower than needed for LANSCE**
  - 2x – 4x increase desirable
- **Reliability not yet acceptable – needs better packaging**
- **Currently no firm plans to continue this development**
  - Lack of personnel
  - Lack of budget

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