NSTX

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Proposed Facility Enhancements for NSTX Upgrade

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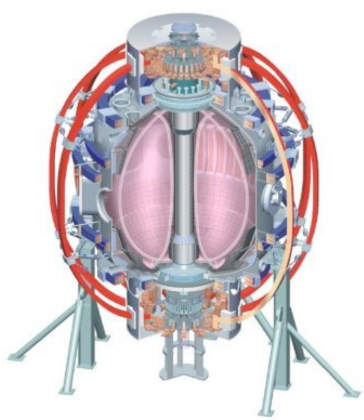
V. A. Soukhanovskii for the LLNL Collaboration Team

NSTX-U Facility Enhancement Brainstorming Meeting

Princeton, NJ

7 February 2012



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LLNL proposals for NSTX-U facility enhancements

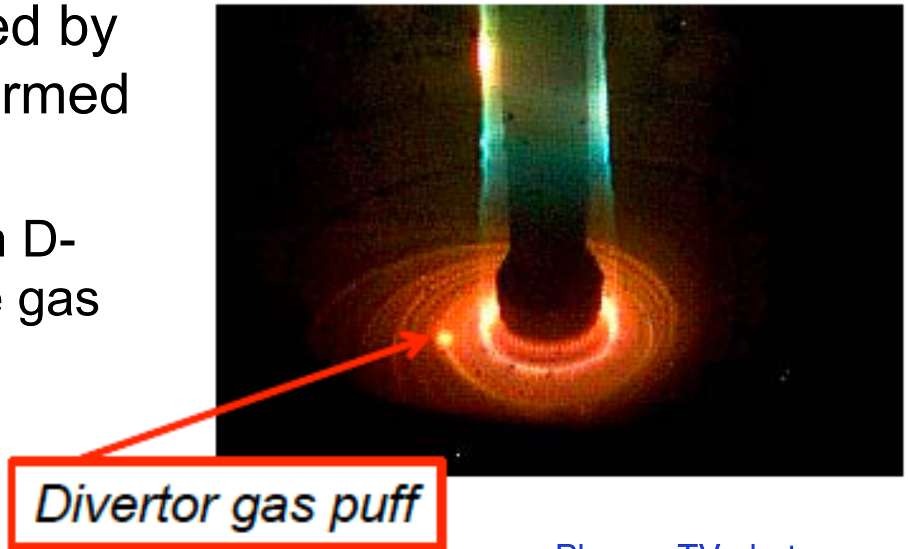
1. Divertor Gas Injector Upgrades for radiative divertor feedback control (gas actuators)
2. Supersonic Gas Injector Upgrades
3. Glow Discharge Cleaning System Upgrades
4. Vacuum vessel and Infrastructure upgrades for divertor Thomson Scattering diagnostic

LLNL proposed development of real-time feedback control of radiative divertor for NSTX-U

- Proposed and partially funded as part of DoE ECRP Award in 2010
- Goal: steady-state feedback control of divertor heat flux and detachment compatible with pedestal stability and H-mode core confinement metrics – critical for NSTX-U 12 MW 2 MA 5 s discharges
- Use diagnostic signal indicative of divertor detachment / reduced heat flux as **control parameter** and pass it on to PCS for fast gas valve control for divertor impurity seeding control (**actuator**)
- Control parameters (diagnostics side):
  - PFC temperature / heat flux monitoring (e.g., fast IR diodes)
  - P_{rad} (e.g., fast bolometers, AXUV diodes, VUV spectroscopy)
  - Recombination rate (D Balmer, Paschen lines), Divertor ion current (e.g., Langmuir probes), D or Impurity pressure (e.g., Optical Penning gauge)
  - Pedestal pressure, core impurity density, MARFE monitoring, etc
- Actuators:
  - Gas valves (midplane and divertor)

Upgrades to divertor gas injection system (D-GIS) motivated by NSTX-U divertor experiments

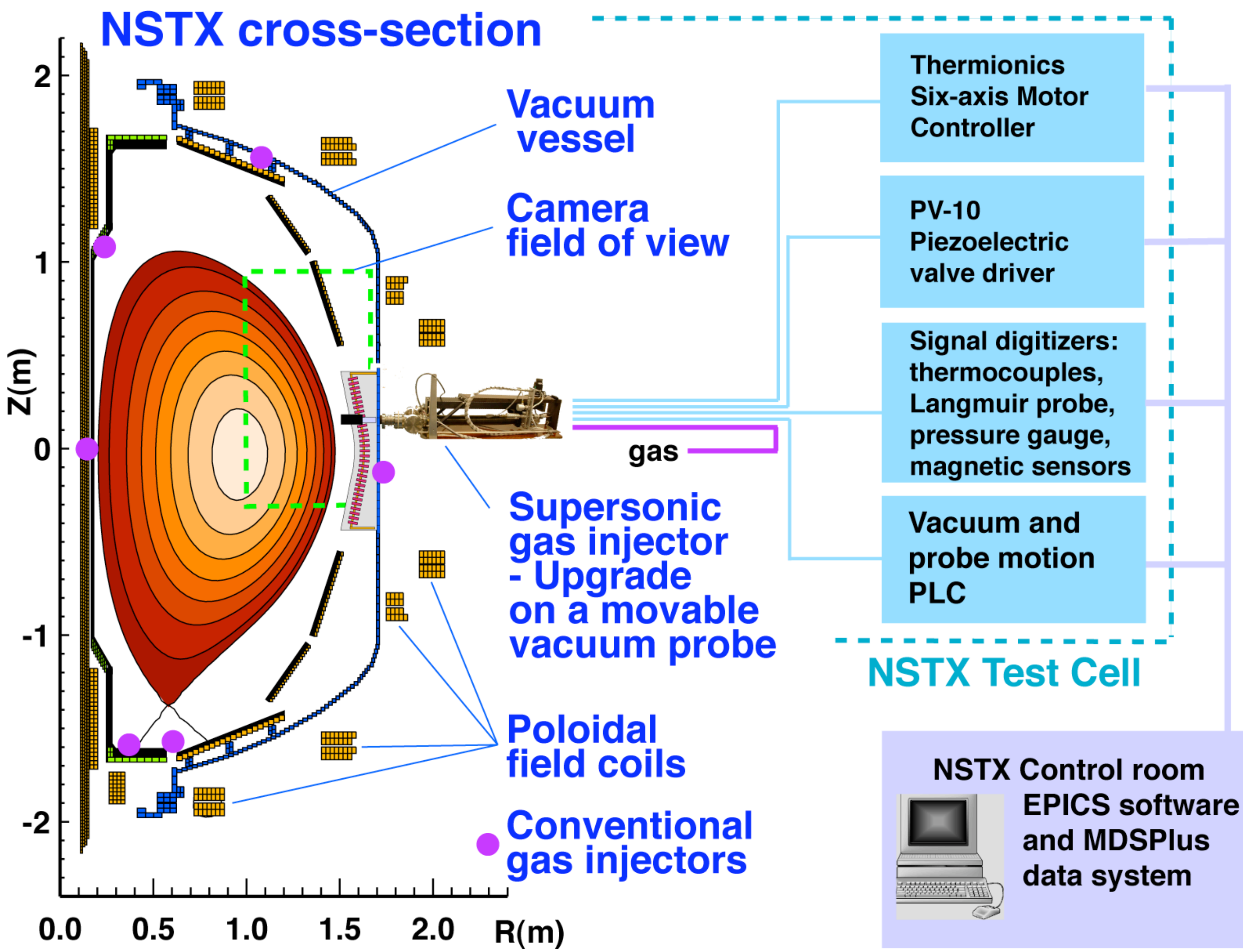
- NSTX (present) D-GIS design motivated by divertor detachment experiments performed in 2005-2008:
  - Gas delivery system is shared between D-GIS and SGI (connected to one remote gas bottle)
  - All components rated to 100 PSI
  - One divertor gas port in CHI gap
  - Pre-programmed PZV control from vacuum operator PC



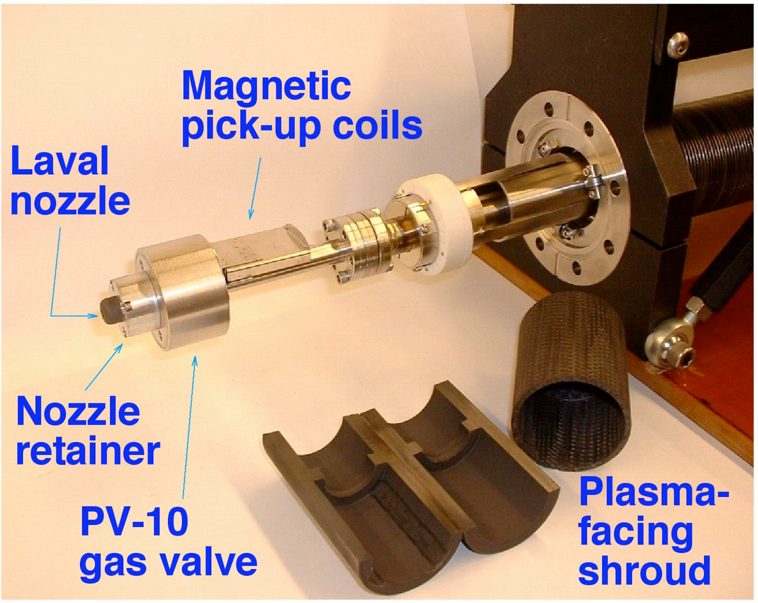
Plasma TV photo courtesy of F. Scotti

- Proposed D-GIS enhancements:
  - Make four toroidally symmetric gas ports (add in-vessel gas lines)
  - Make remotely controlled independent gas delivery system to handle several gases (D_2, He, Ne, Ar, CD_4, …)
  - Add pre-programmed control to PCS
  - Develop and implement feedback control algorithm

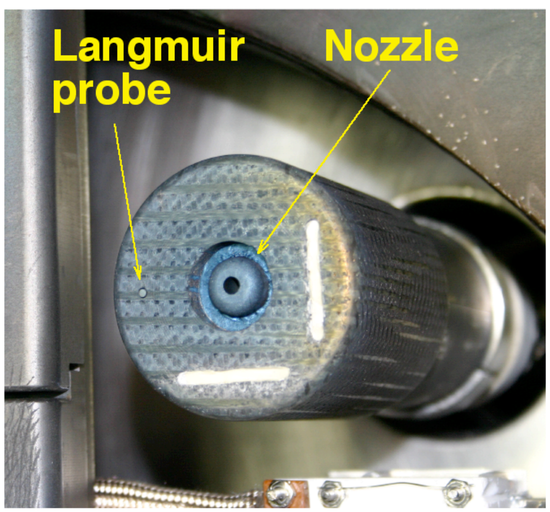
Supersonic gas injector is a complex computer-controlled high gas pressure apparatus

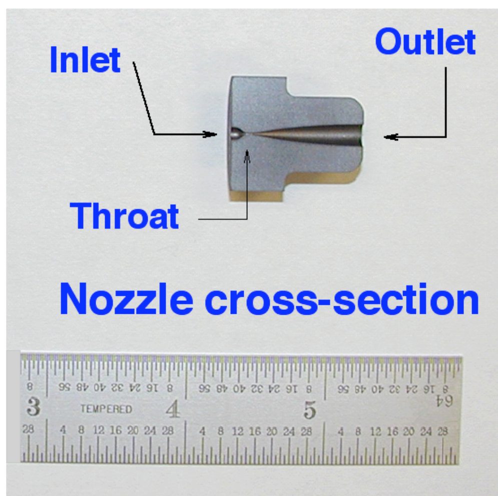


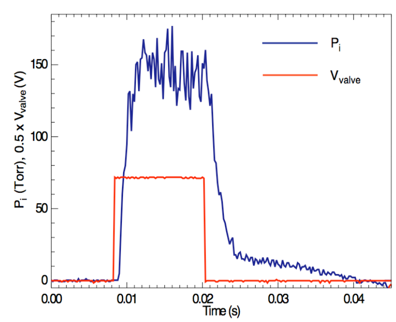
Supersonic gas injector consists of Laval nozzle and piezoelectric valve

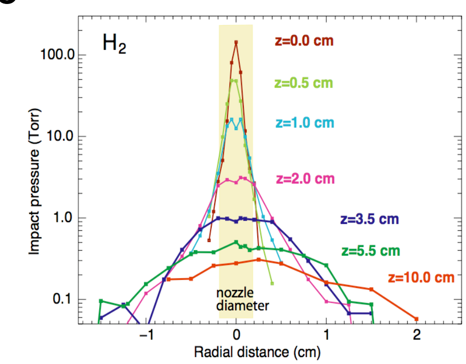


- SGI is operated at flow rates 20-250 Torr l /s
- Supersonic deuterium jet properties:
  - Jet divergence half-angle: 6º - 25º (measured)
  - Mach number M = 4 (measured)
  - Estimated: T ~ 60 - 160 K, $n < 5 \times 10^{23}$ m^{-3}, v_{flow} = 2.4 km/s, v_{therm} ~ 1.1 km/s
  - Nozzle Re = 6000









SGI upgrades proposed in 2008 but never implemented…

- Use present valve / nozzle for stationary SGI mounted on the wall in the shadow of limiter
- Use movable probe from present SGI to prototype cryogenic SGI
  - Design and make new metal nozzle
  - Use non-piezo valve (EM, pneumatic, others)
  - Design cryogenic cooling system (liquid N_2)
- Present limit on reservoir pressure (5000 Torr = 96 PSI) seems sufficient for fueling with present nozzle 250 Torr l / s

- Develop PCS control

Propose to re-examine present glow discharge system for optimization toward NSTX-U

Shimada, EPS 2011

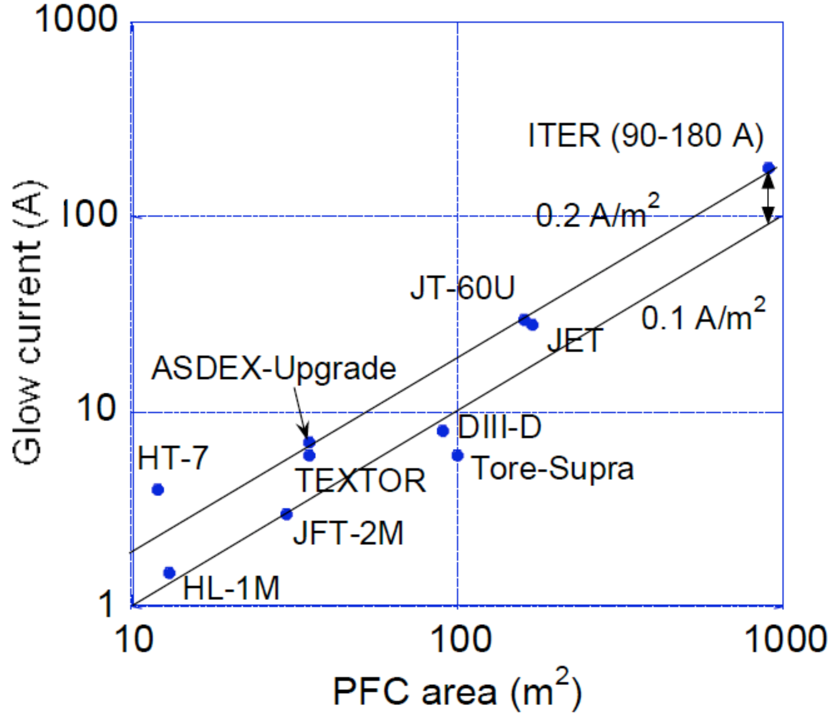


Fig. 1 Glow current vs. PFC area compiled from measurements on current devices

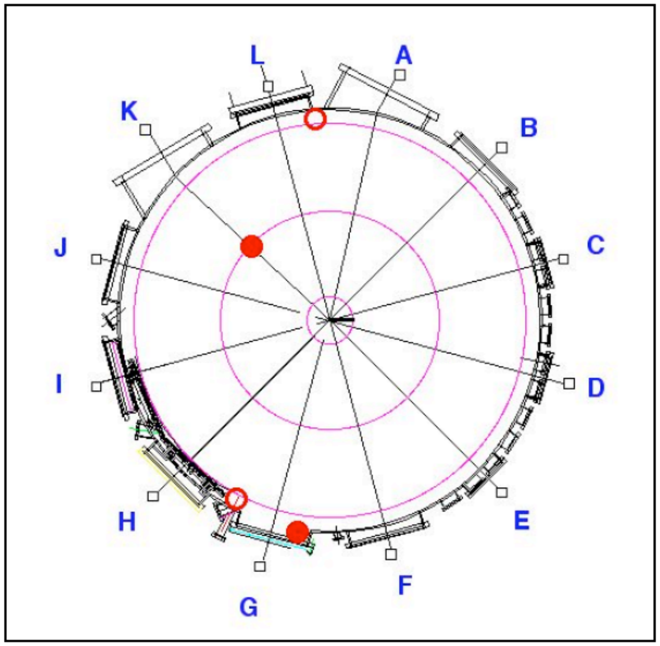


Fig. 1. Schematic diagram showing layout of inital NSTX HeGDC system (1999-2005) [open circles at Ports G and L] and the location of the upgraded HeGDC system anodes [solid circles, Ports G and K] relative to the vessel ports. The MGP is mounted at Port-K; the present fixed GDC anode is at Port-G.

- Tokamak GDC figure of merit: 0.1-0.2 A/m^2
- NSTX PFC area 41 m^2, current ~3.5 A, two anodes
- NSTX-U: greater PFC area -> need higher current (?), more uniform coverage (?)

LLNL is proposing Divertor Thomson Scattering system for divertor and lithium studies in NSTX-U

- Unique ("true") divertor T_e and n_e measurements
  - DTS systems available only on DIII-D and TCV
- LLNL progress toward NSTX-U DTS
  - Initial identification of implementation issues on NSTX (done in 2008)
  - Maintenance and operation of DIII-D DTS (planned and performed now)
  - Conceptual design of DTS diagnostic (planned for 2013-2014)
    - Determine laser beam and collection optics geometries
    - Specify system elements and project performance
- **Need to keep DTS in mind when facility enhancements are planned**