A Platform for Characterizing the Thermodynamic Stability and Proportional Scintillation Signals of Argon-Xenon Mixtures

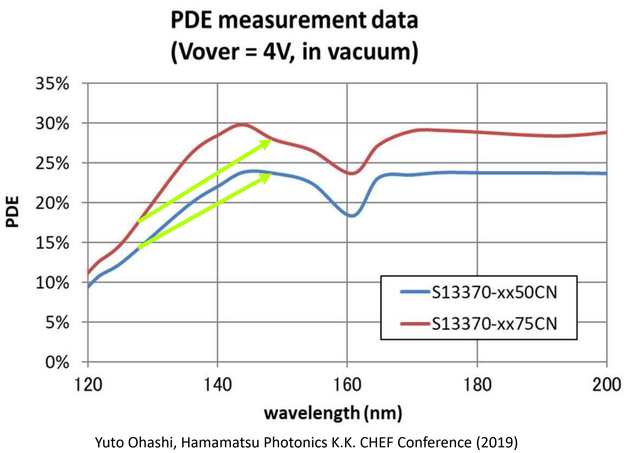
Ethan Bernard[*], Nathaniel Bowden[*], Igor Jovanovic[‡], Eli Mizrachi[†], Sergey Pereverzev[*], Teal Pershing[*], David Trimas[‡], and Jingke Xu[*]

* Lawrence Livermore National Laboratory Nuclear and Chemical Sciences Division
† University of Maryland Physics Department
‡ University of Michigan Department of Nuclear Engineering and Radiological Sciences

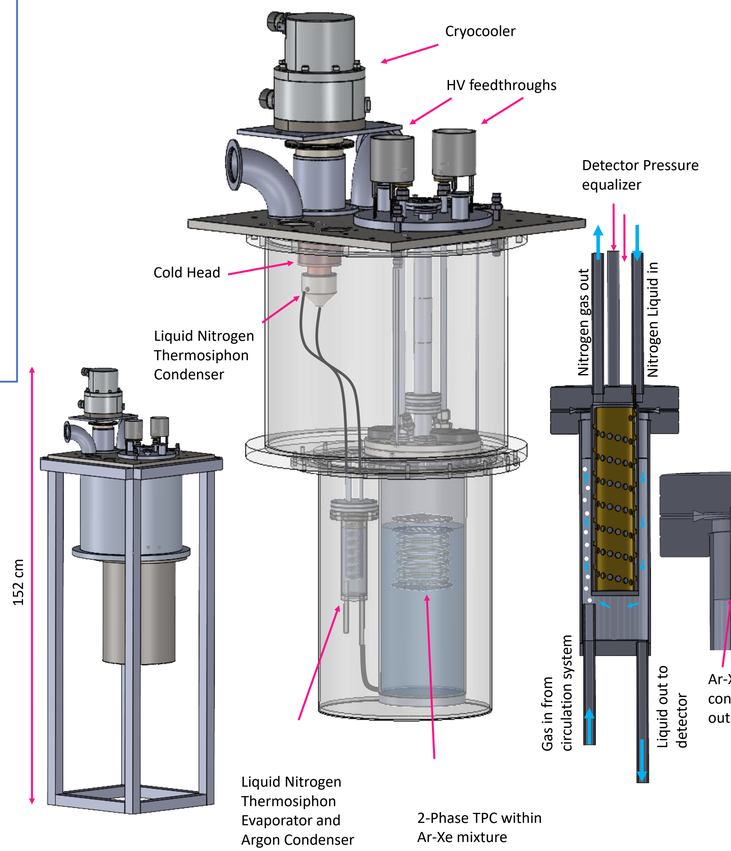
Chemistry of Electroluminescence Light Production

Fast e^- + Ar → slow e^- + Ar* (Threshold 11.8 eV)	Inelastic collision of electron with argon
Fast e^- + Xe → slow e^- + Xe* (Threshold 8.4 eV)	Inelastic collision of electron with Xenon
Ar* + Ar → Ar_2 Ar* + Xe → ArXe Xe* + Xe → Xe_2	Argon and xenon form metastable excimer molecules
Ar_2 → 2 Ar + hν ← 128 nm; 2 - 3 μs lifetime ArXe → Xe + Ar + hν ← 147 nm; 300? ns lifetime Xe_2 → 2 Xe + hν ← 178 nm; 25 ns lifetime	Excimer molecules decompose and emit photons.

The presence of Xenon in the gas allows faster light emission at longer wavelengths.



Yuto Ohashi, Hamamatsu Photonics K.K. CHEF Conference (2019)



Considerations for Circulation System Design

Xenon strongly prefers the liquid over the gas

50 ppm in gas → 1.25 to 2.25% in liquid

Unwanted Distillation

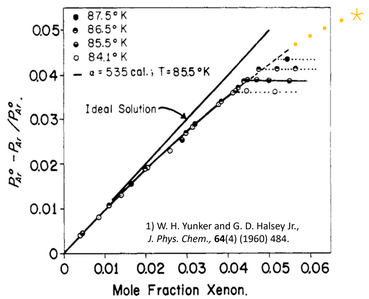
Henry's Law: $H^{cc} = \frac{Fractional\ concentration\ of\ Xe\ in\ liquid}{Fractional\ concentration\ of\ Xe\ in\ gas}$ ~ 250 – 450 at 90 - 95 K

- Xenon is concentrated in the liquid by the evaporation process. Circulation must allow this concentrated xenon to mix with the main argon bath.
- We will apply heat broadly to the detector can walls below the liquid surface.

Unwanted Freezing

- Returning gas must condensed in a way that prevents gas from contacting very cold surfaces, where xenon may freeze and clog the plumbing.
- We isolate the Ar-Xe mixture condensation in a separate volume that is upstream of the main detector bath. This ensures that only liquid of low xenon concentration is exposed to the cold components in the condenser.
- Unwanted freezing sets a hard limit on the concentration of xenon that can be added to the liquid. This solubility limit increases as a function of pressure and temperature. (See below.)

How much Xe can we dissolve in LAr?



- Assume 5% vapor pressure suppression due to Xe addition
- Assume 5% vapor pressure suppression: Vapor curve of 94.84 K @ 2.0 Bar
- Assume extension of the solubility vs temp plot:

5% Xe fraction in liquid may be a comfortable place to operate.

100 / T = 1.0544 from plot at right
Predicts n^{Sat} = 7.1%

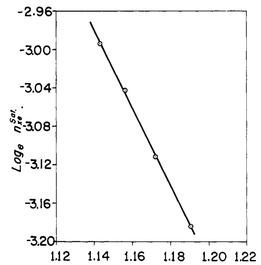
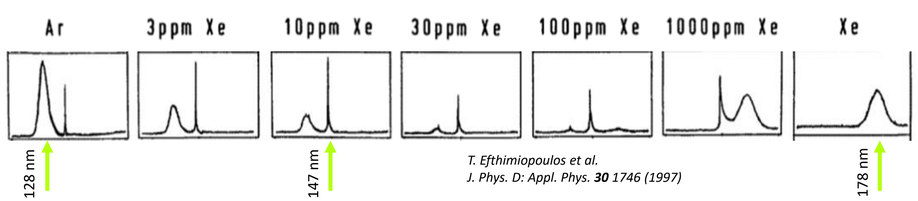


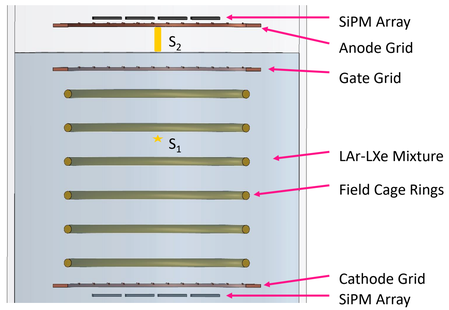
Fig. 2.—Ln n_{Xe}^{Sat} vs. 100/T °K.

Temp. (°K.)	α (cal./mole)
84.0	560 ± 55
85.5	536 ± 39
86.5	504 ± 39
87.5	504 ± 20
	Av. 535 ± 58

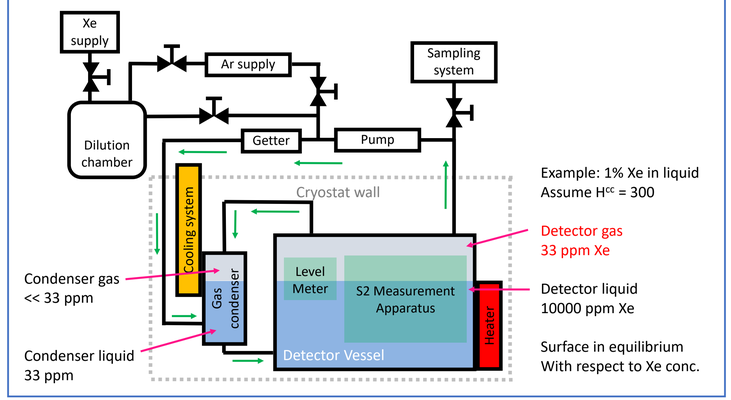
Addition of Xe to Ar Gas Mixtures Under Ion Beam Excitation Shifts Emission to Longer Wavelengths



T. Efthimiopoulos et al.
J. Phys. D: Appl. Phys. ***30*** *1746 (1997)*



Argon-Xenon Mixture Circulation Scheme



This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344 and prepared by LLNL under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

Lawrence Livermore National Laboratory