The Performance of a Continuous Supersonic Expansion Discharge Source

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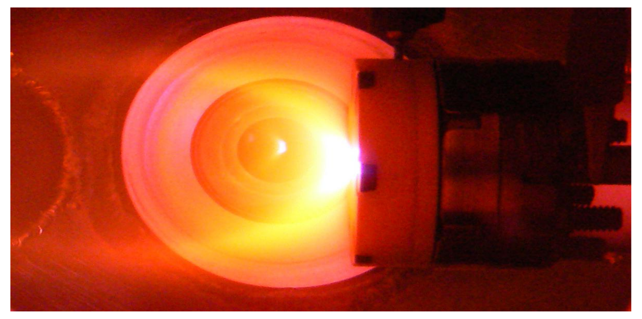
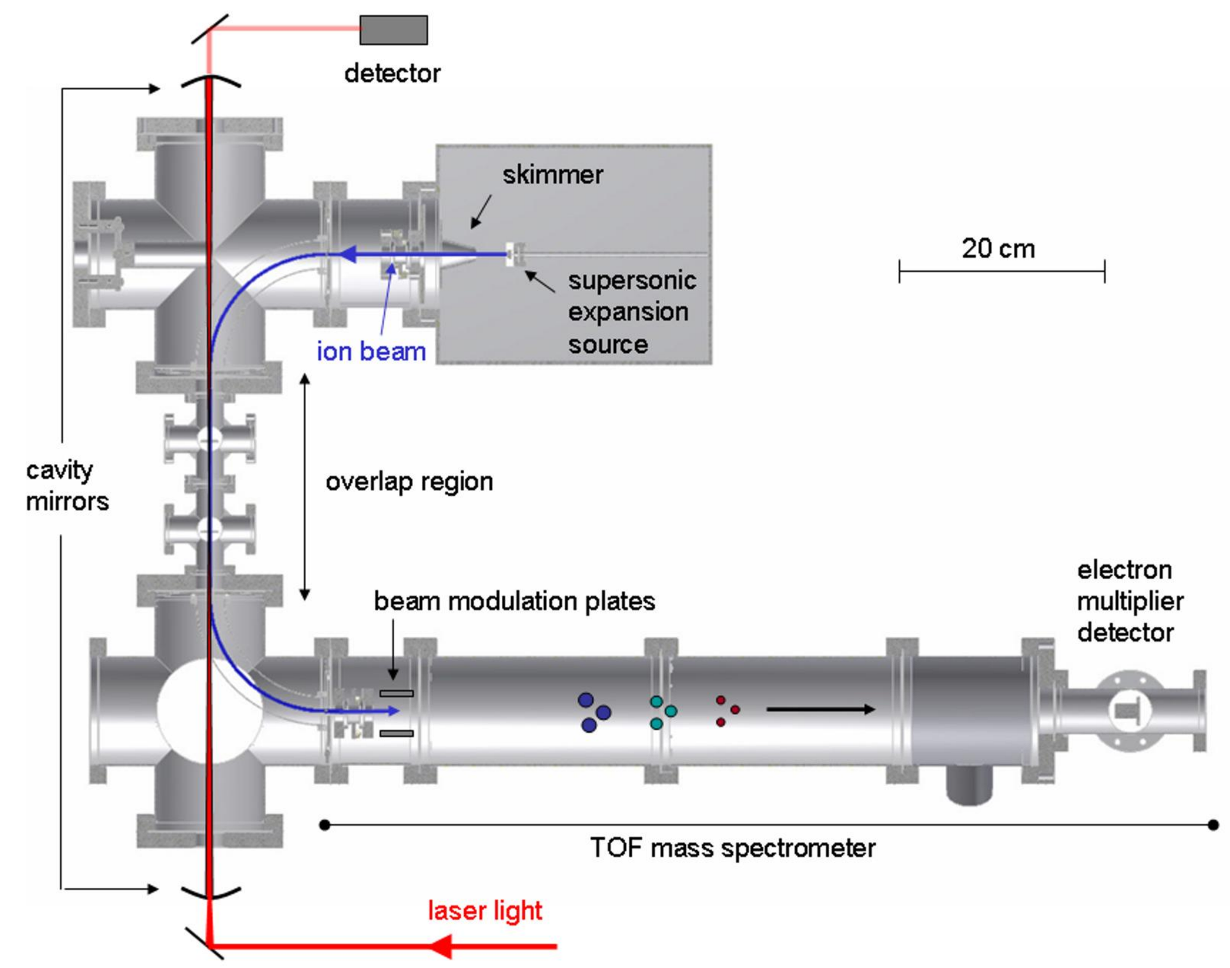
What is a Supersonic Expansion?

A supersonic expansion is created when a high pressure gas expands into vacuum through a small orifice. Subsequent adiabatic cooling results in rotationally cold molecules. When coupled to an electrical discharge, ions can be produced with temperatures below 30 K.



Motivation



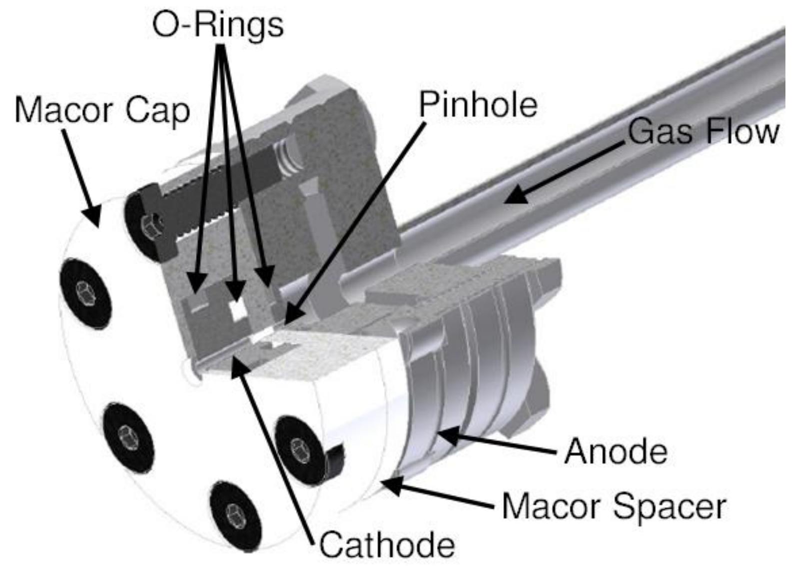
The McCall research group is interested in obtaining high resolution gas-phase spectra of astronomically important ions at astrophysically relevant temperatures. In order to accomplish this, our group has been developing an instrument called SCRIBES (Sensitive Cooled Resolved Ion BEam Spectroscopy). This technique combines a supersonic expansion discharge source with sensitive laser spectroscopy, and mass spectrometry.

For more information see T07, "SCRIBES: Sensitive Cooled Ion BEam Spectroscopy"

Source Design

For use with SCRIBES, the source was designed to be durable, modular, and robust. The self-aligning source was based around a 1 1/3" conflat flange and o-rings provided a leak-tight seal.

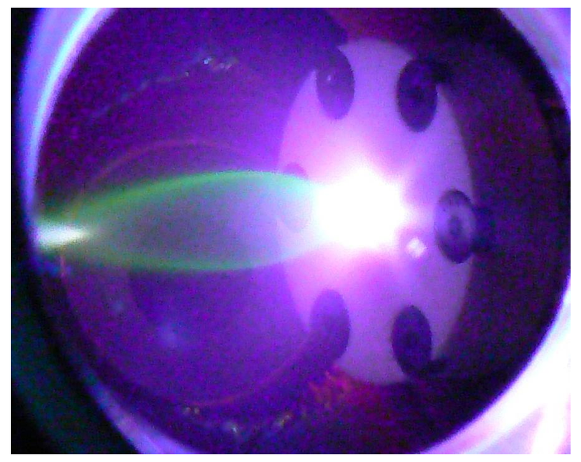
Design parameter space to be explored:
- Pinhole geometry
- Pinhole diameter
- Spacer thickness
- Pressure
- Current



Initial Performance Results

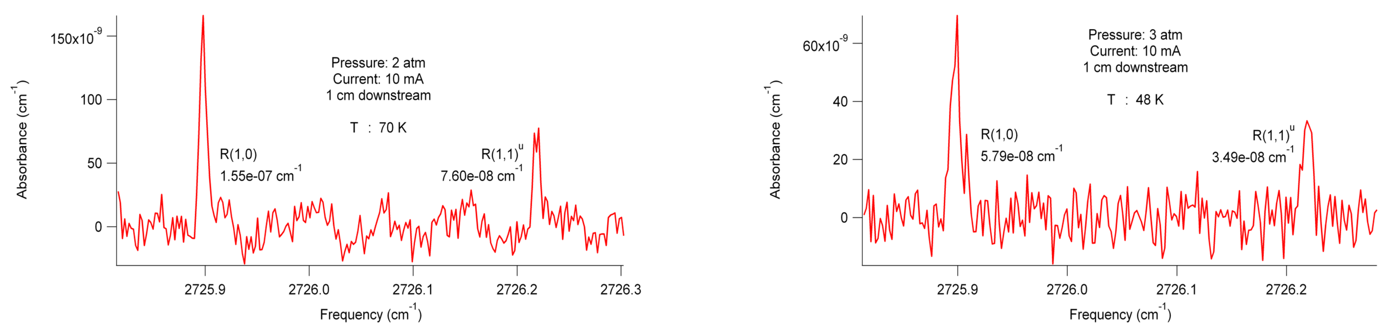
Durability

Initial testing has shown that the design is capable of withstanding continuous operation. Previous failure modes include the fracture of the macor pieces and/or improperly sealed components. Both of these can be attributed to either machining imperfections and/or over-tightening. Despite this, our current source has sustained operation for over 200 hours with no visible signs of degradation.

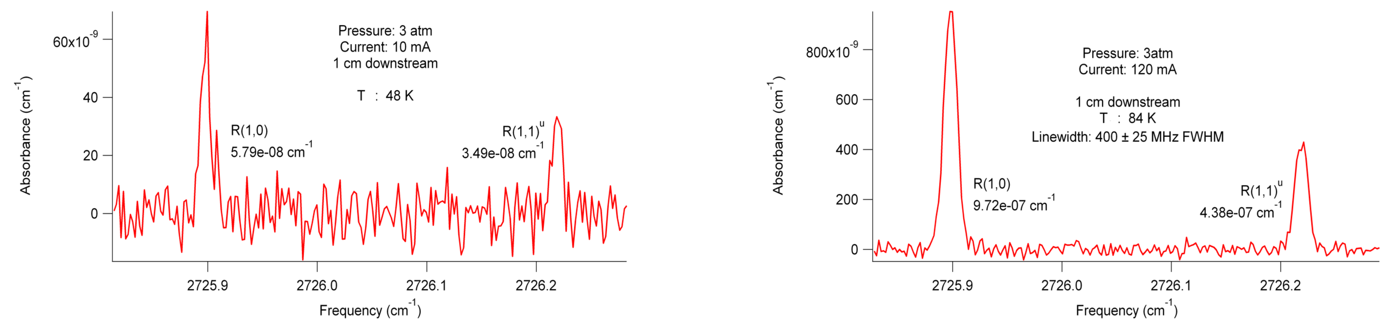


Spectroscopic Characterization

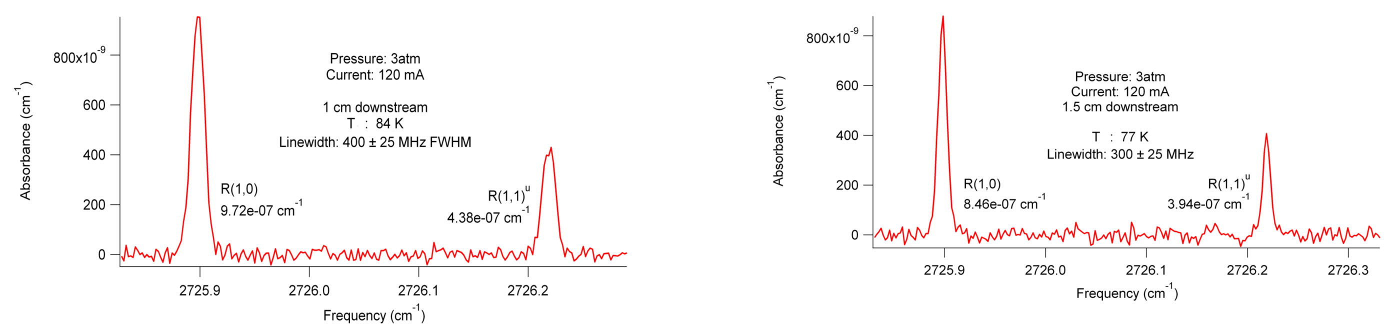
Spectra were obtained at 2 and 3 atmospheres of backing pressure. At 1 atm, the expansion was not supersonic. When increasing the pressure from 2 atm to 3 atm, the intensity of lines and the temperature decreased at the same current.



Spectra were also obtained after varying the current from 10 to 130 mA. It was observed that as the current increased, the signal increased.

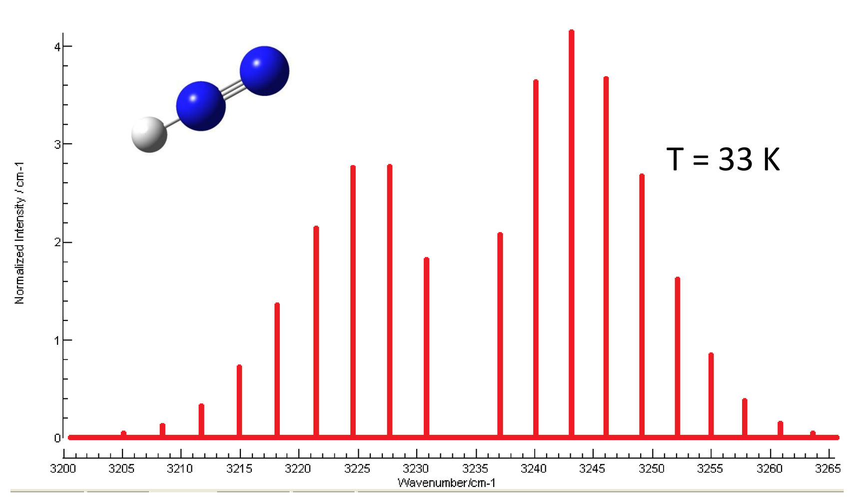


Finally, the expansion was probed at different axial positions downstream of the nozzle. Observed linewidths decreased by a factor of 25% when moving from 1 to 1.5 cm.



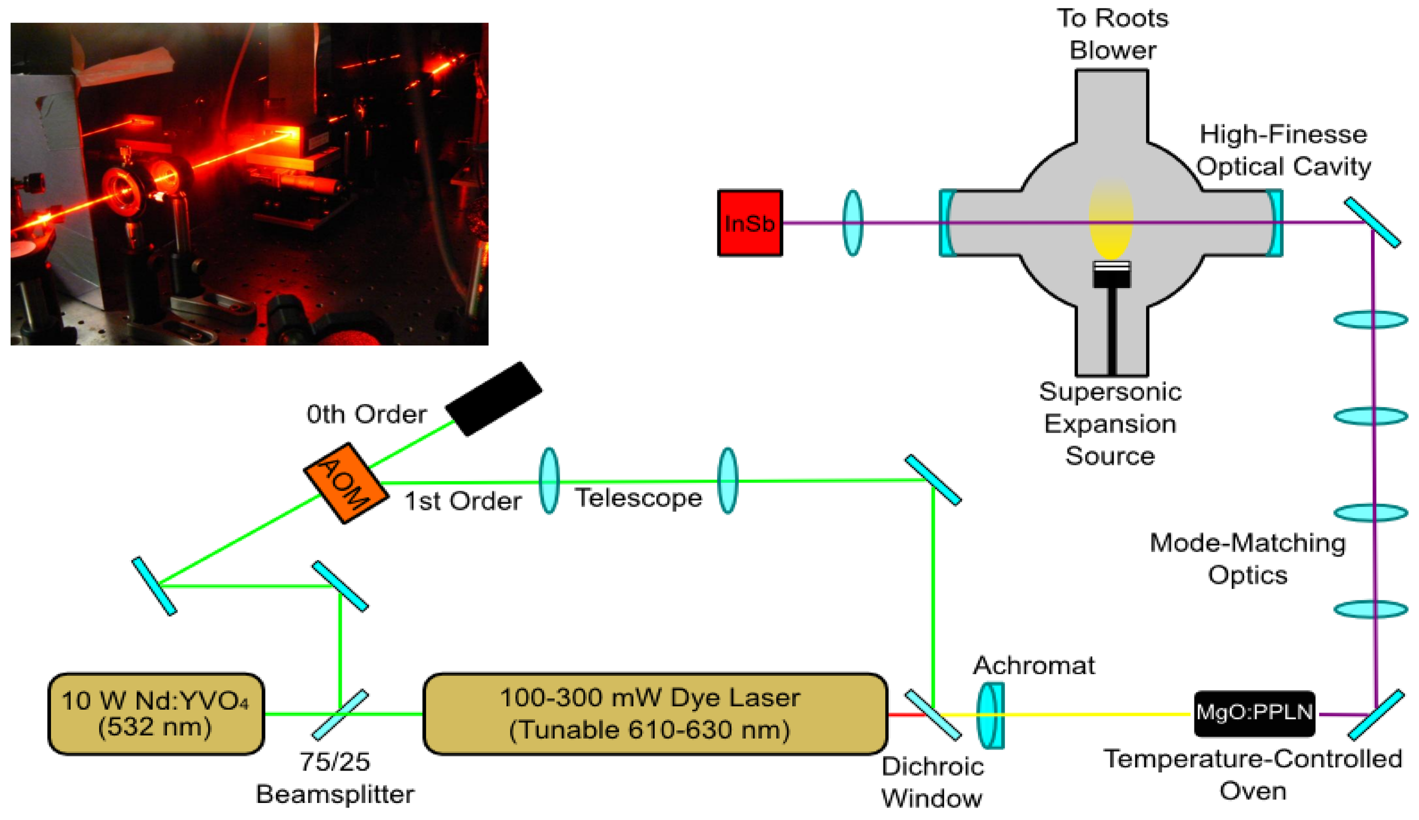
Future Work

- Additional testing using the ($\nu_1 \leftarrow 0$) band of HN_2^+ which has a smaller rotational constant than H_3^+.
- Determine the effects of nozzle geometry and size on ion production and cooling.
- Skimmer design.
- Integration with SCRIBES.

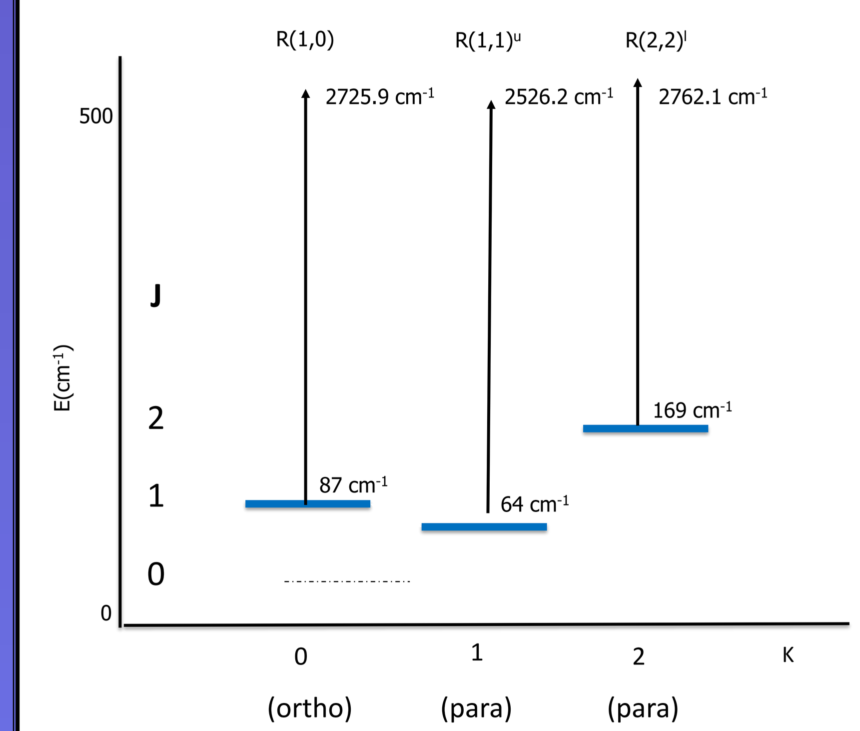


Experimental Design

DFG: 500 – 700 µW of tunable mid-IR light (2.2-4.8 µm)
Spectroscopic Technique: Cavity Ring-down Spectroscopy



Target Ion: H_3^+



The first high resolution spectrum of H_3^+ was recorded in 1980 by Takeshi Oka. Its chemistry has important implications in dense and diffuse interstellar clouds and is used as a probe of astrophysical conditions.

We are probing the low J states within the R branch of the ν_2 fundamental band.

Due to its rather large rotational constant, B = 43.56 cm^{-1}, H_3^+ is not expected to cool as efficiently as an ion with a smaller rotational constant.

Temperature can be calculated from a ratio of the intensities of any combination of all three lines.

Bibliography

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