



Overview of In Situ Instruments for Deployment in Extreme Environments

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- In Situ Geochronology Instrument
- Laser Ablation Sampling Instrument
- Micro Hygrometer
- Micro Lidar
- Atmospheric Electron X-Ray Spectrometer
- Nuclear Magnetic Resonance Spectrometer

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Funding

NASA (UPN632)

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Objective

Develop technology necessary to construct an instrument for in situ analysis of crystallization ages of igneous rocks.



Conventional Geochronology

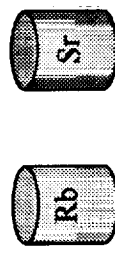
Field sampling of rocks.



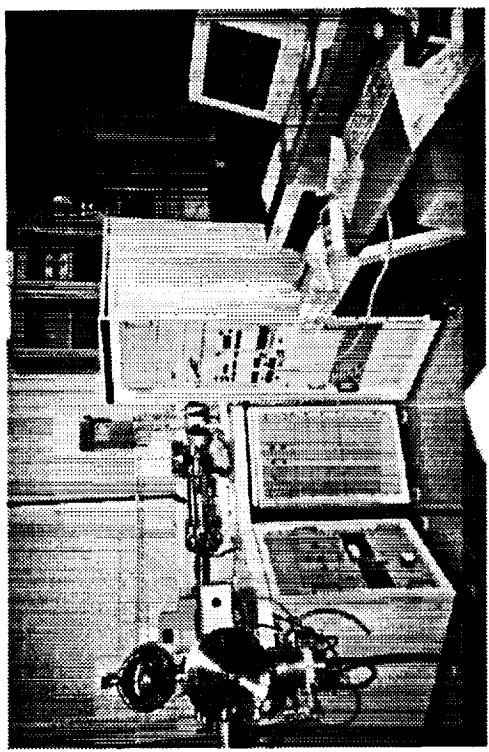
Separation into mineral grains.



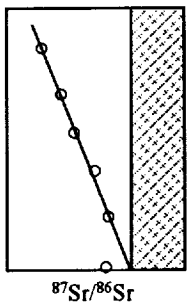
Wet chemistry for elemental separation.



Measure isotope concentrations using a high-precision mass spectrometer, such as this thermal emission-magnetic sector mass spectrometer at the University of Pittsburgh.



Generate isochron.

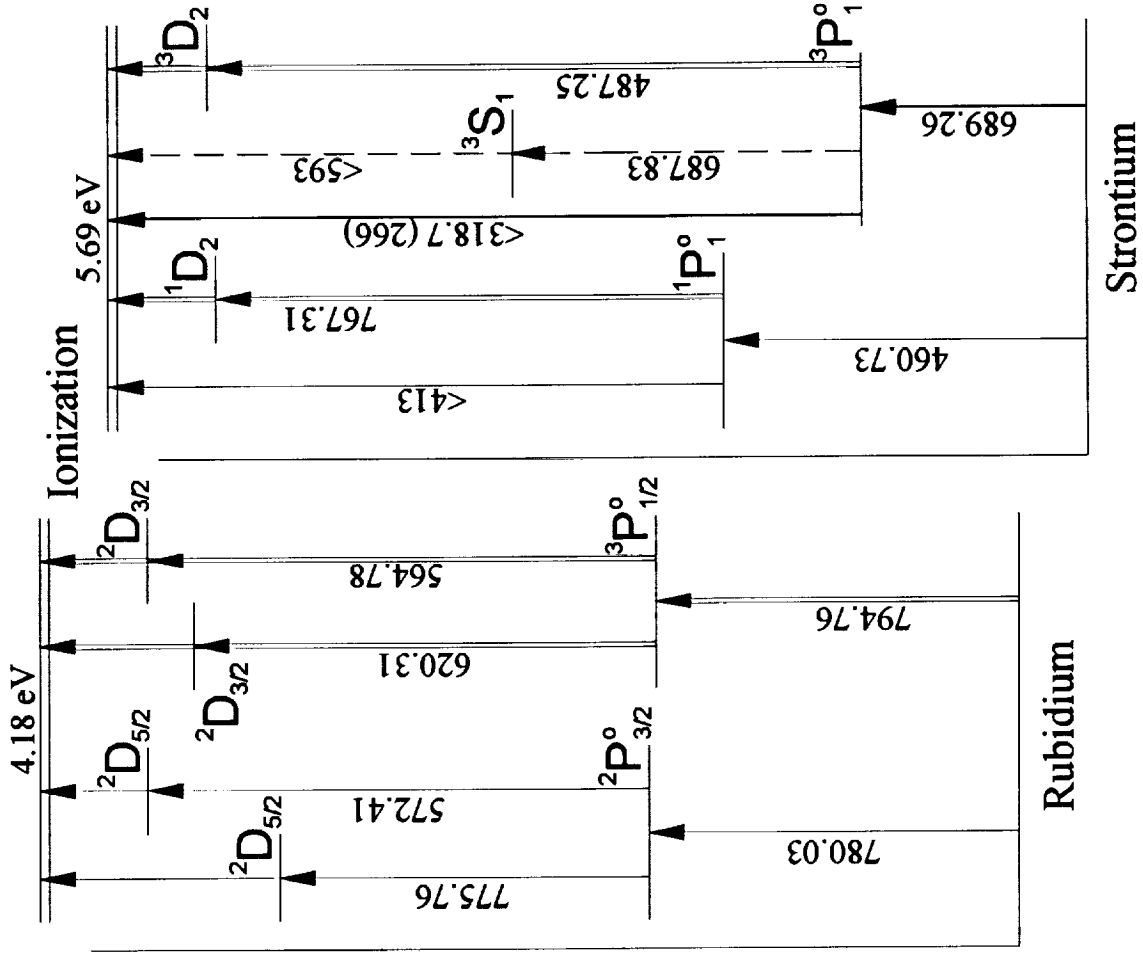


The time since crystallization is extracted from the isochron using a line fit to the data points and the known decay rates of the parent isotope.



Resonance Ionization

In this process, electrons are removed from atoms by successively promoting them to higher-level excited states, until the ionization potential is reached. Shown here are (—) demonstrated, (---) modeled, and (==) possible resonance ionization schemes for Rb and Sr. Resonance ionization of Sr has been demonstrated in our laboratory.



Advantages

- Eliminates wet chemistry by selectively ionizing only the radiogenic elements.
- High ionization efficiency compared to other techniques.

Challenges

- Develop feasible schemes.
- Identify tunable narrow-linewidth semiconductor lasers having appropriate wavelengths.
- Calibrate ionization rates for even/odd isotopes.



Laser Ablation

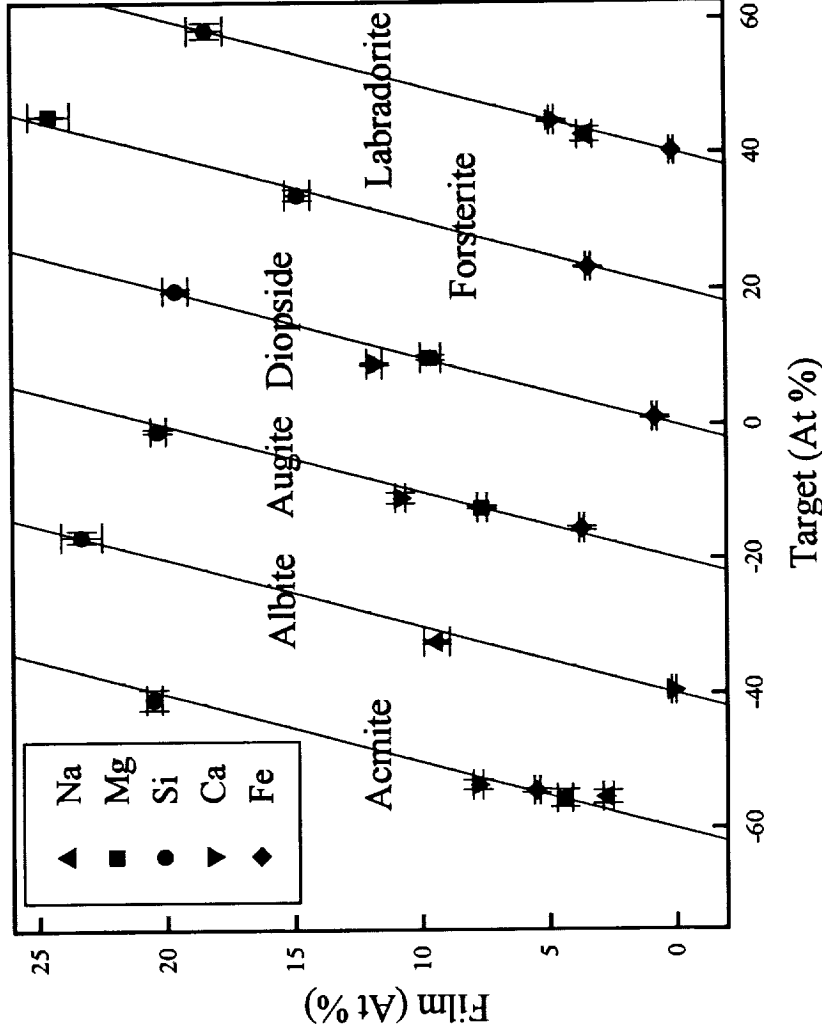
In this process, a pulsed high-power laser is focused on a rock sample. Thermal, chemical, and electronic interactions trigger formation of a plume consisting of atoms, ions, molecules, clusters, and particulates. Laser ablation of silicate minerals in our laboratory preserved stoichiometry of major elements.

Advantages

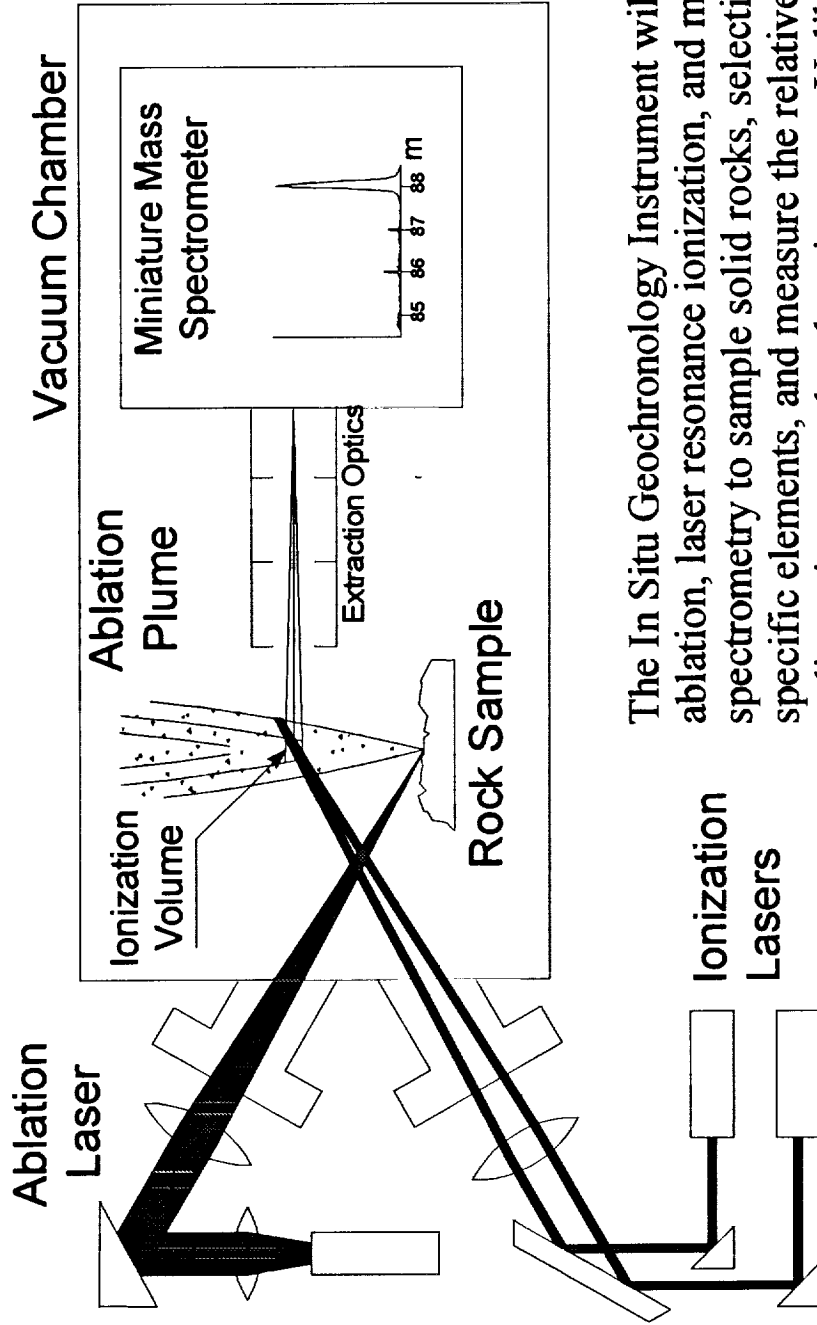
- Direct sampling.
- Mechanical simplicity.

Challenges

- Develop robust high-efficiency laser.
- Evaluate effects on elemental and isotopic stoichiometry.
- Minimize formation of non-neutral non-atomic products.
- Develop feasible scheme for sample transport into instrument.



“Elemental Fractionation in Ultraviolet Laser Ablation of Igneous Silicate Minerals Relevant to Mars,” M.E. Taylor, D.L. Blaney, and G. Cardell, submitted to *Geochimica et Cosmochimica Acta*, 1999.



The In Situ Geochronology Instrument will use laser ablation, laser resonance ionization, and mass spectrometry to sample solid rocks, selectively ionize specific elements, and measure the relative quantities of radiogenic parent-daughter isotopes. Unlike conventional terrestrial geochronology techniques, the instrument will not require a chemical separation stage between sampling and ionization, minimizing complexity and consumables.

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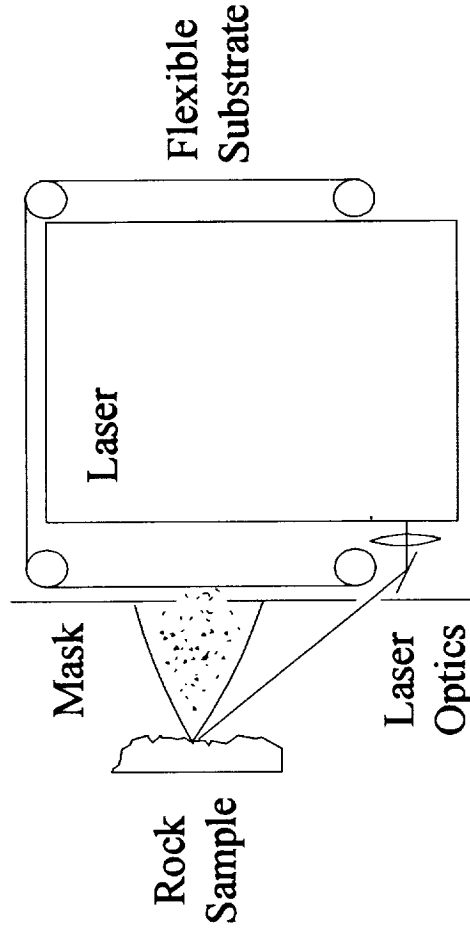
NASA (DRDF)

Objective

Develop technology necessary to construct an instrument for sampling of a large number of igneous rocks.

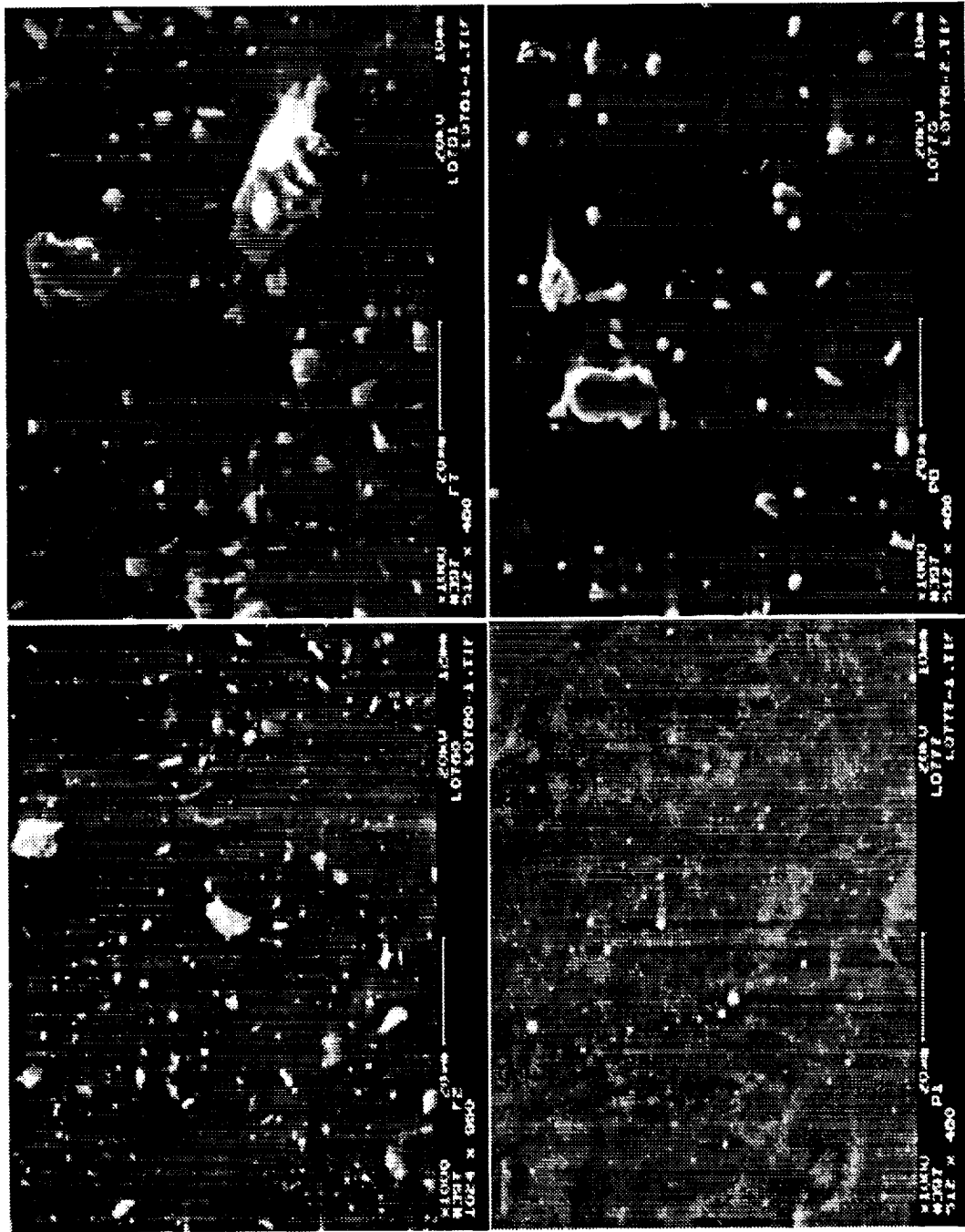


The primary components of this instrument are a pulsed laser, a mask, and a substrate. Laser ablation is used to generate plumes comprised of atoms and particulates. Plume constituents are transmitted through an aperture in the mask and deposited onto the substrate. Prior to ablation of each distinct geological site, the substrate is translated relative to the mask to provide a distinct substrate site for deposition. The substrate sites are cataloged and referenced to the corresponding geological sites. This instrument has the potential to collect a large number of thin film samples at a low operational cost per sample. The simplicity of design minimizes the possibility of malfunction.



Challenges

- Develop robust high-efficiency laser.
- Evaluate effects on elemental and isotopic stoichiometry.
- Balance formation of film and particulates.



Scanning electron micrographs showing particulates produced in vacuum by laser ablation of (a) albite at 266 nm, (b) albite at 1064 nm, (c) augite at 266 nm, (d) augite at 1064 nm. The scale bar is 20 μ m.

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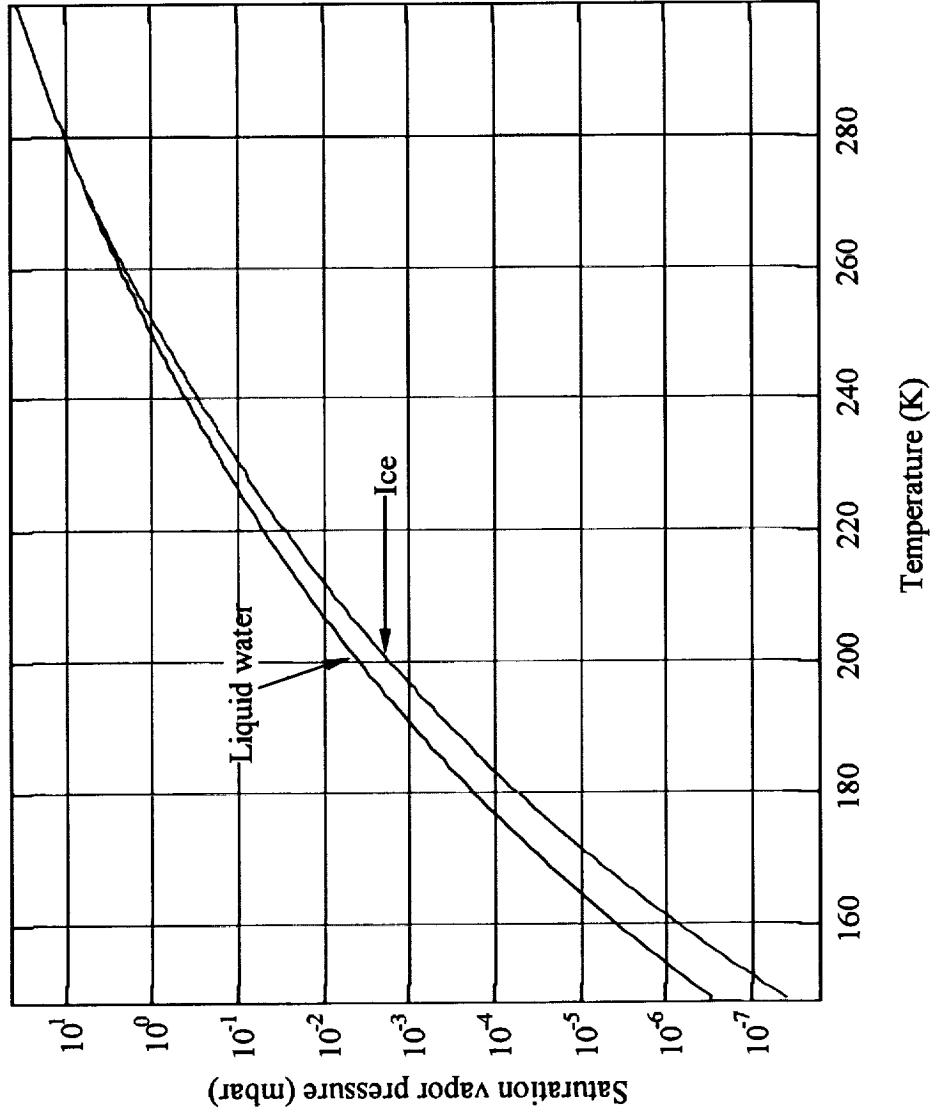
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NASA (Code YS)

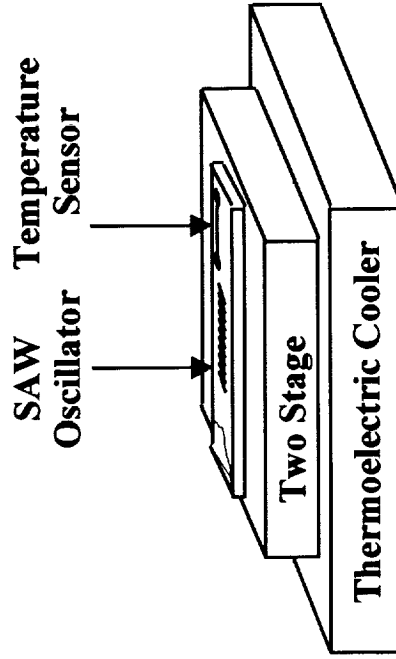
Objective

To provide an instrument for in situ analysis of humidity.



Surface Acoustic Wave Dewpoint Hygrometer

Condensation on surface induces
change in surface acoustic wave
frequency.



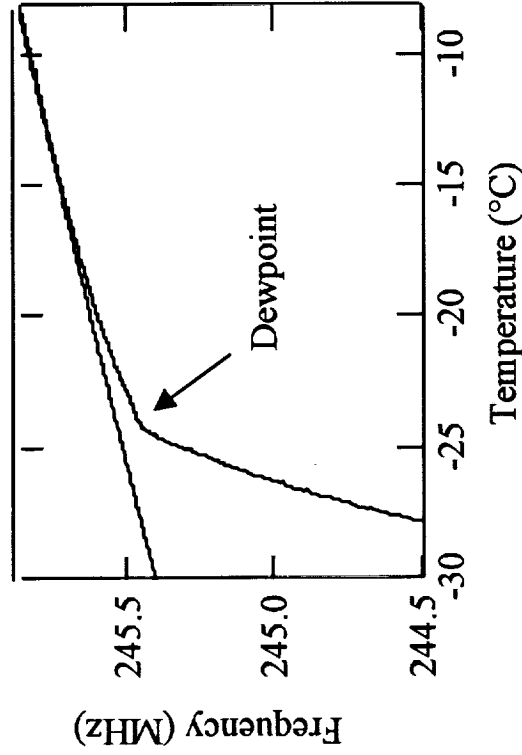


Hygrometer Types

Technology	Principle	Advantages	Disadvantages
Solid State	Change in electronic properties.	Compact geometry. Low power.	Slow response. Hysteresis. Poor reproducibility. Contamination sensitive. Low temperature limitation.
Absorption	Optical absorption spectroscopy.	Water-specific.	Calibration critical. Contamination sensitive. Large volume required.
Conventional Dewpoint	Optical scattering induced by condensation on a chilled mirror.	Direct measurement. No hysteresis.	High-mass high-power. Contamination sensitive.
Micro Dewpoint	Change in surface acoustic wave frequency induced by condensation.	Compact geometry. Fast response. Direct measurement. Wide dynamic range.	Contamination sensitive.



Temperature Control

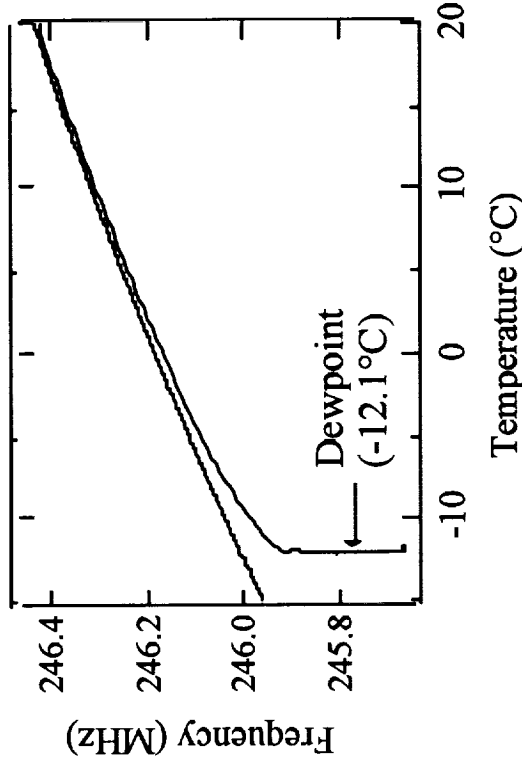


Frequency depends on temperature and condensation.

Below dewpoint, condensation accumulates.

Abrupt change in slope when ramping through dewpoint. Discrete dewpoint measurement.

Frequency Control



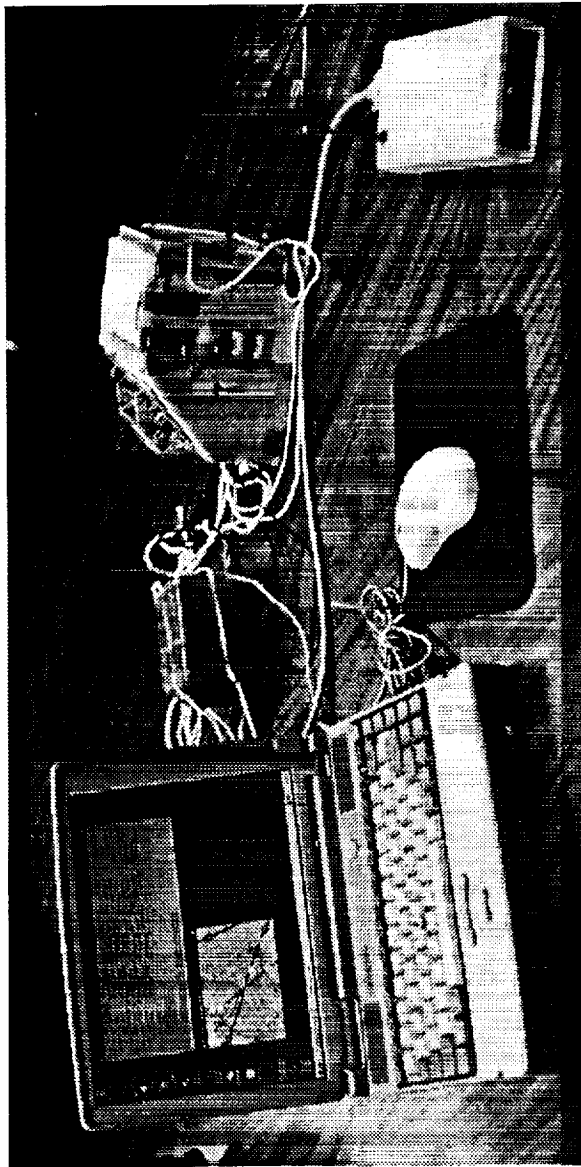
Temperature depends on frequency and condensation.

Below threshold frequency, equilibrium with water vapor determines temperature.

Continuous dewpoint measurement.

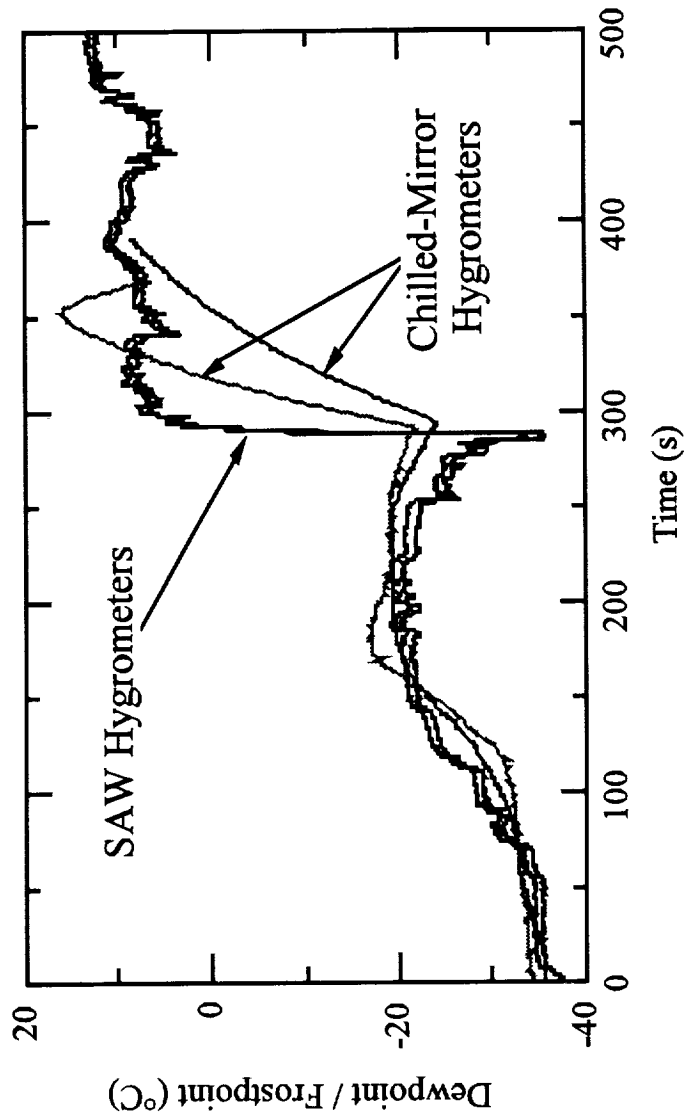
Radiosonde Flight

Balloon payload and ground station hardware.



DC8 Flight

Prototype validation.



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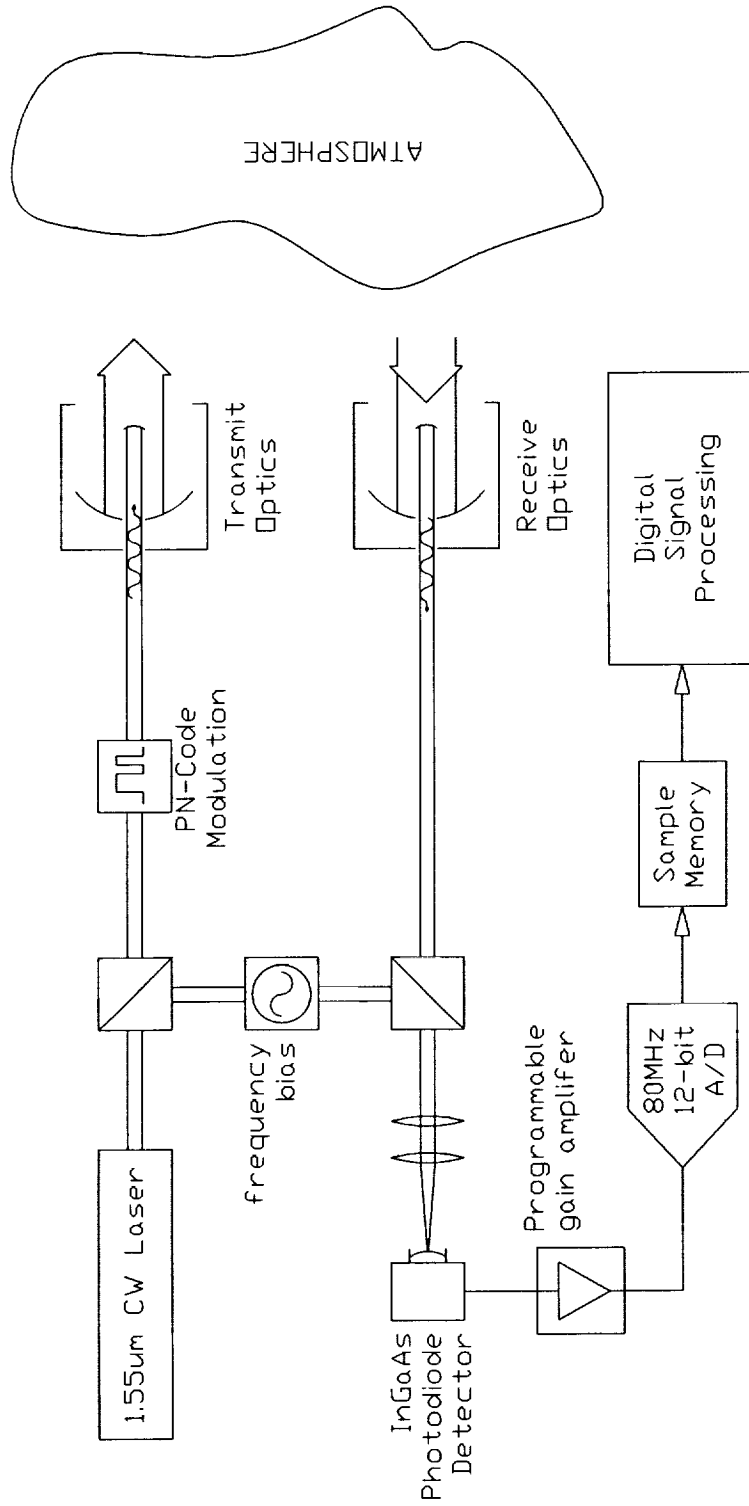
Funding

NASA (UPN632)

NASA (PIDDP)

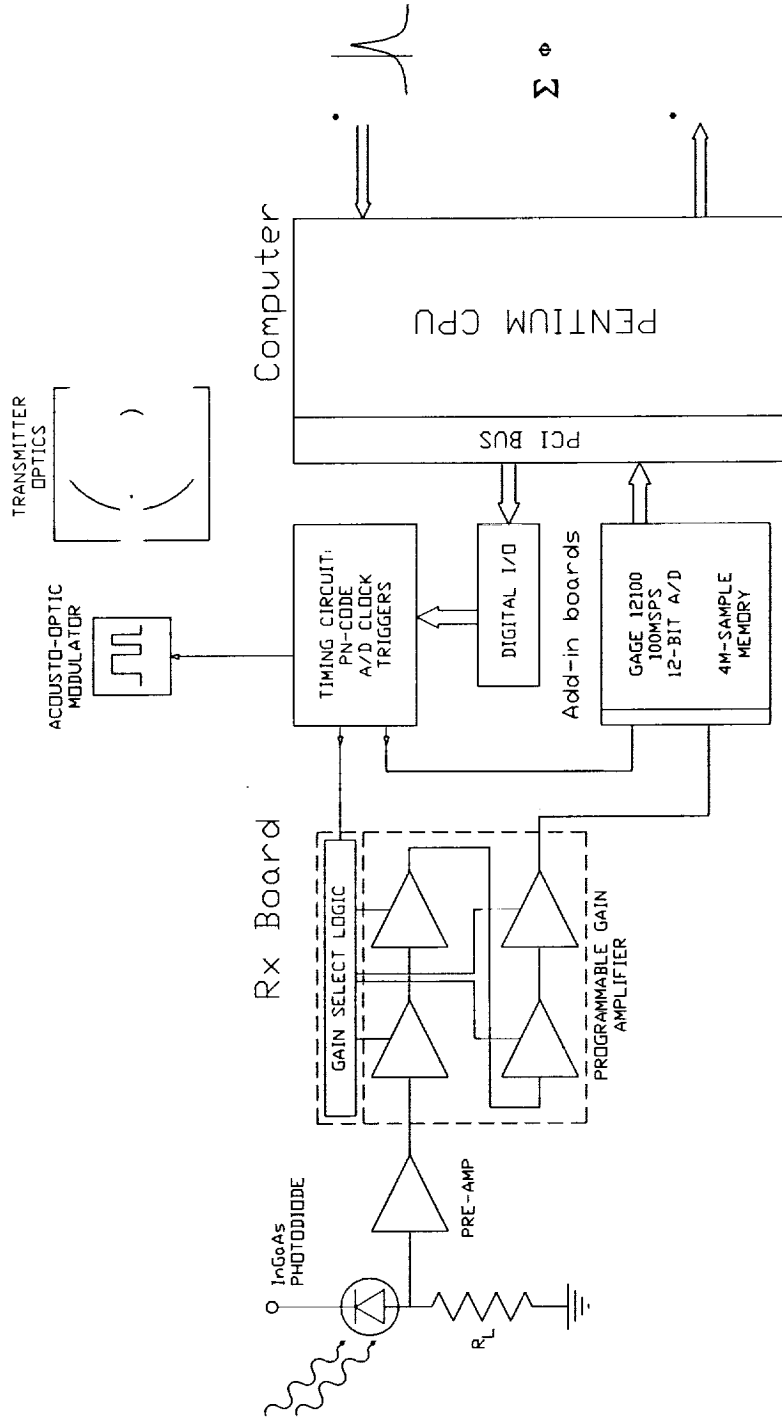
Objective

Develop technology necessary to construct an instrument for in situ profiling of atmospheric boundary layer wind and dust scattering with an altitude range of 0-2 km, vertical resolution of 50m, and LOS velocity accuracy of 1-2 m/s.



Prototype System

The transmitted signal is generated through PN-code modulation of a continuous wave laser consisting of a 1.55um photodiode and an erbium doped fiber amplifier. The local oscillator is a portion of the unmodulated transmitter signal biased by 20MHz using an acousto-optic modulator (for determination of the direction of the Doppler shift and hence that of the wind). The local oscillator and the received signal are mixed using a beam-splitter / lens combination. The combined signals are focused onto an InGaAs photodiode, and the beat frequency and range information are extracted in the digital signal processing system by decorrelation with the original modulating code. For compactness, the transmitted and received signals use a single telescope, and polarization dependent optics isolate the signals traveling through the same optical elements.

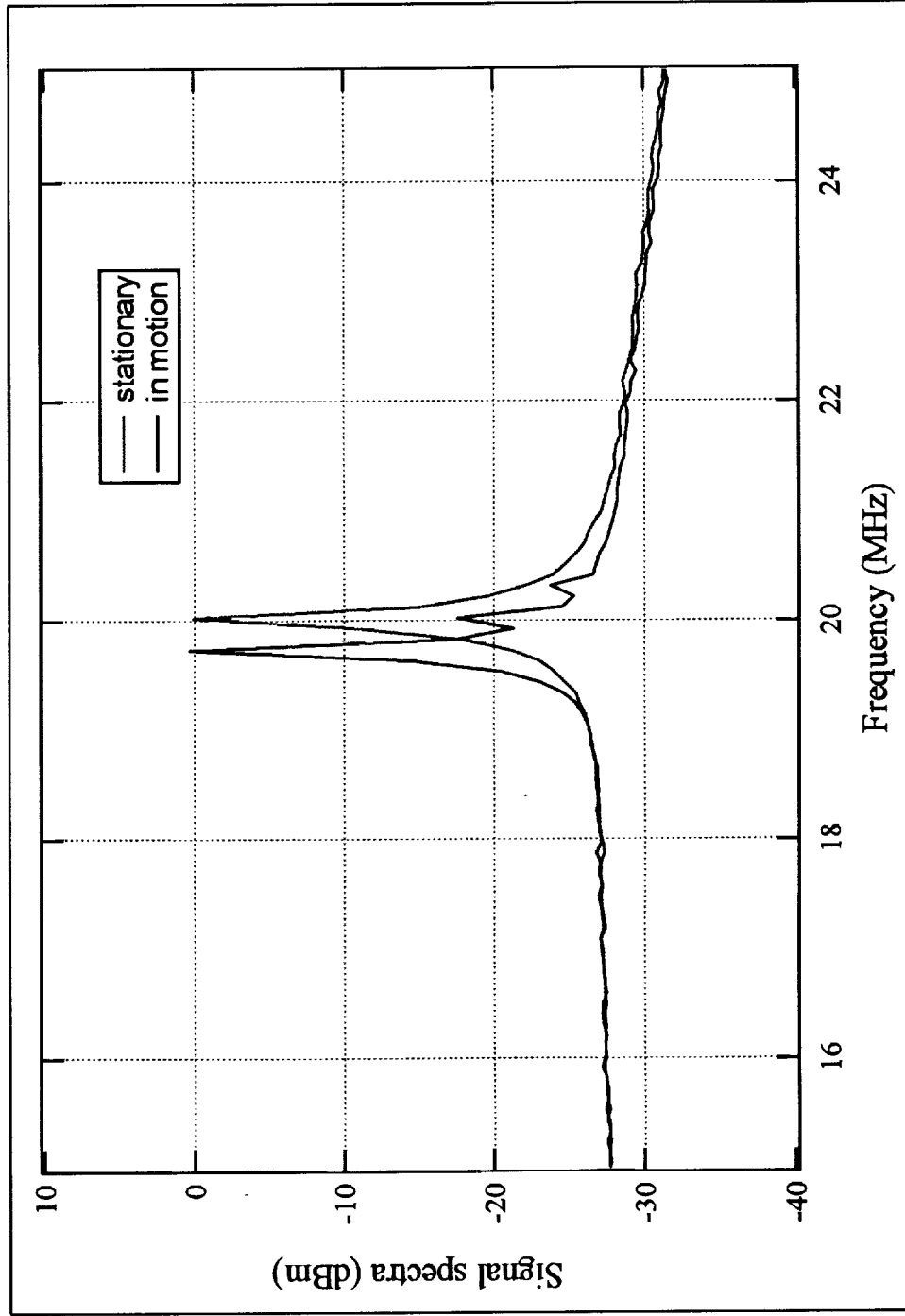


Signal Processing System

The received signal from the InGaAs photodiode detector passes through a high-speed low-noise programmable-gain amplifier and is digitized at 80MHz in phase with the PN-code modulation. The sample data are saved in memory for processing. Data from each PN-code chip are converted (using Fourier Transforms) into a power spectrum, and the frequency bins corresponding to the chips are then decorrelated with the original PN-code, yielding a decorrelated power spectrum for each range. The frequency corresponding to the highest peak in the power spectrum for each bin is returned as the Doppler frequency, which gives the wind speed.



Corner Cube Target
Transmitter Optical Power = 0.9 mw
Integration Time = 20 msec



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Objective

Develop technology necessary to construct an instrument for in situ elemental surface analysis.

Naval Research Laboratory

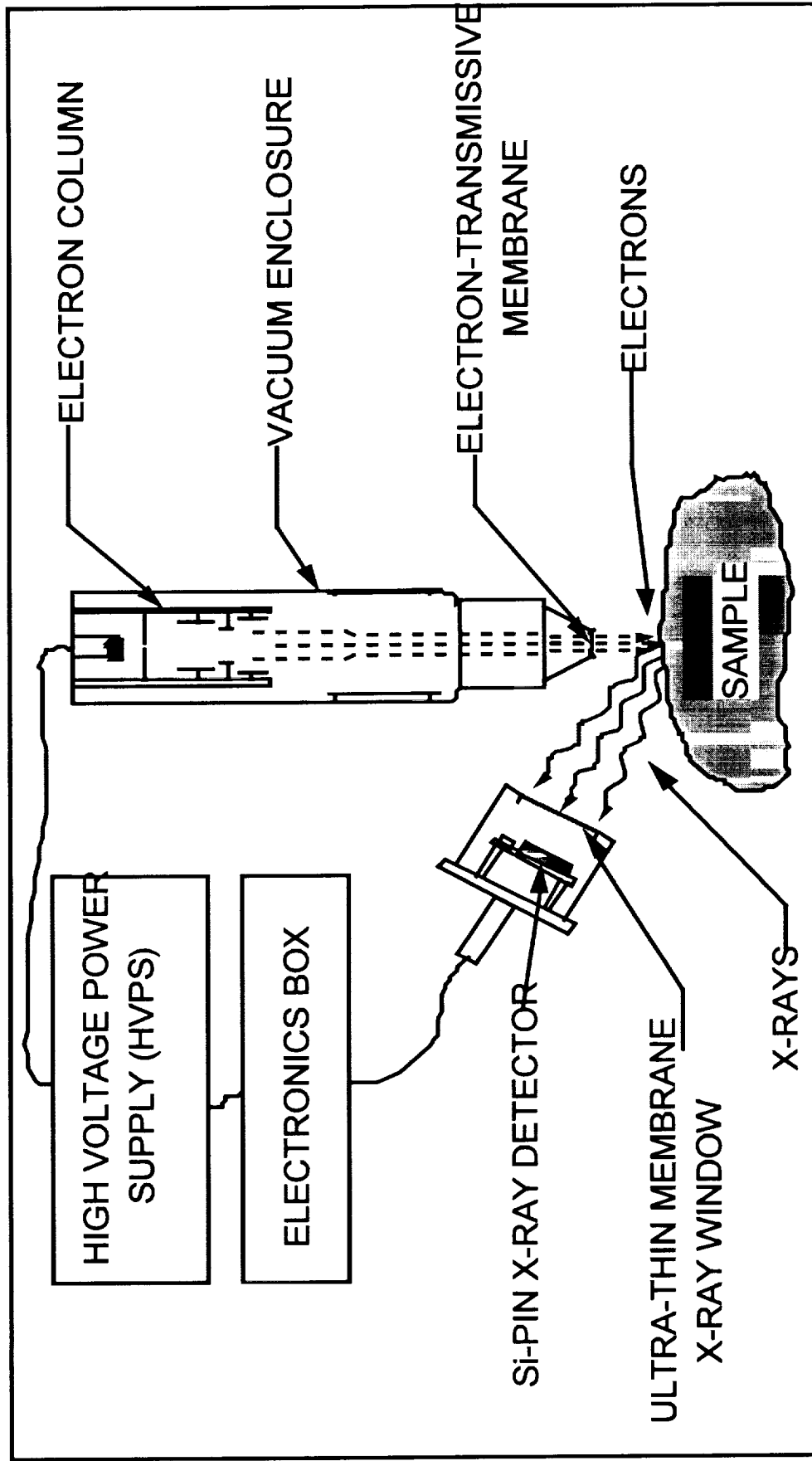
Tim Elam

Langley Research Center

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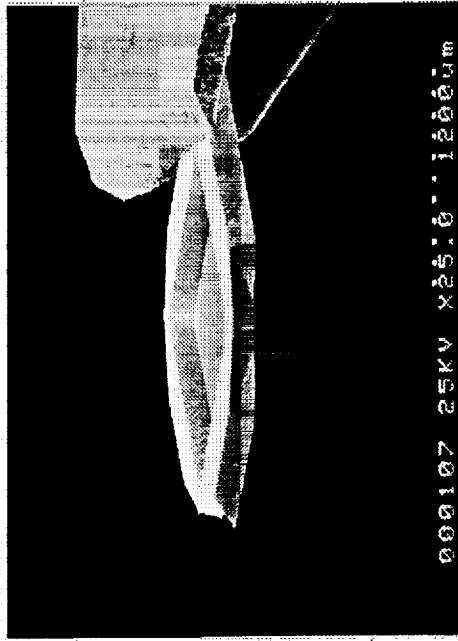


The Atmospheric Electron X-Ray Spectrometer will use an electron beam to excite characteristic x-rays for energy dispersive analysis and thin electron-transparent x-ray-transparent membranes to isolate the electron column and x-ray detector from the planetary atmosphere.





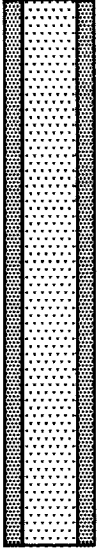
Membrane Fabrication



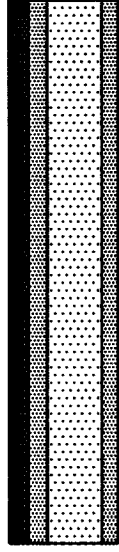
Scanning electron micrograph
of a SiN membrane.

Thickness ~ 200 nm

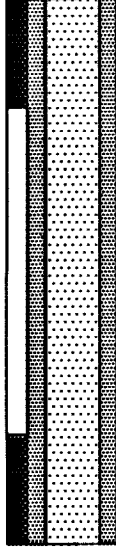
Radius ~ 0.5 mm



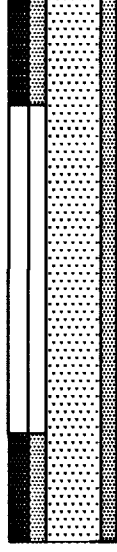
Step 1: Coat Si wafer with SiN.



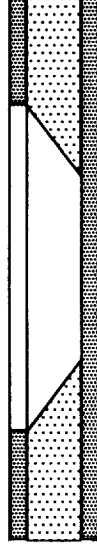
Step 2: Spin on photoresist.



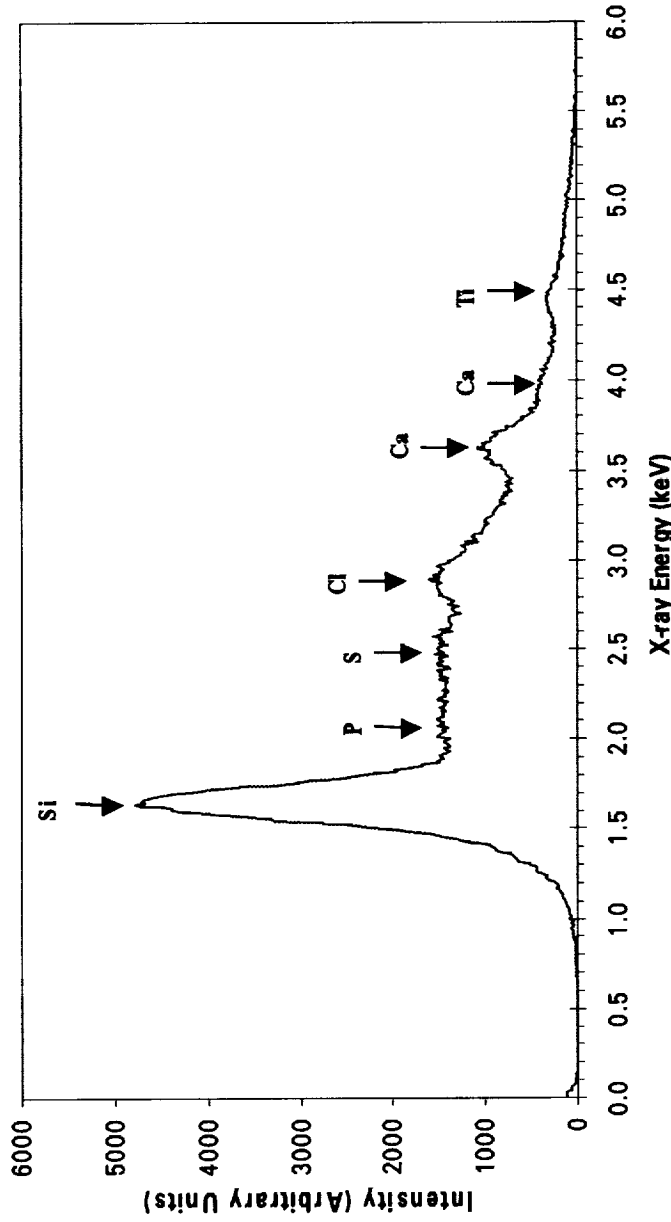
Step 3: Expose and develop.



Step 4: Transfer photoresist pattern
to SiN using reactive ion etching.



Step 5: Use SiN as mask for wet
etching of Si to expose membrane.



Compound	Weight %
SiO ₂	34.5
Al ₂ O ₃	18.5
TiO ₂	3.0
Fe ₂ O ₃	12.4
MnO	0.2
CaO	4.9
MgO	2.7
K ₂ O	0.5
Na ₂ O	1.9
P ₂ O ₅	0.7
Volatiles	21.8

Challenges

- Develop detailed understanding of the instrument operation.
- Build stand-alone prototype
- Explore other effects, i.e. cathodoluminescence, imaging etc.



Force Detected Nuclear Magnetic Resonance Spectrometer



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Objective

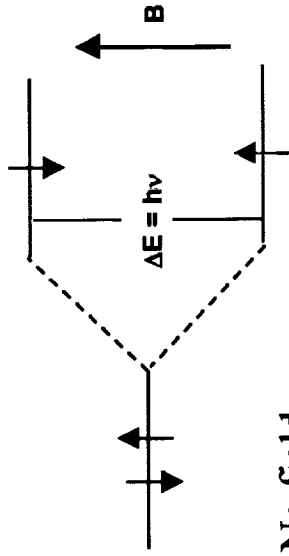
Develop technology necessary to construct an instrument for in situ detection of water and analysis of mineral composition.



Force Detected Nuclear Magnetic Resonance Spectrometer

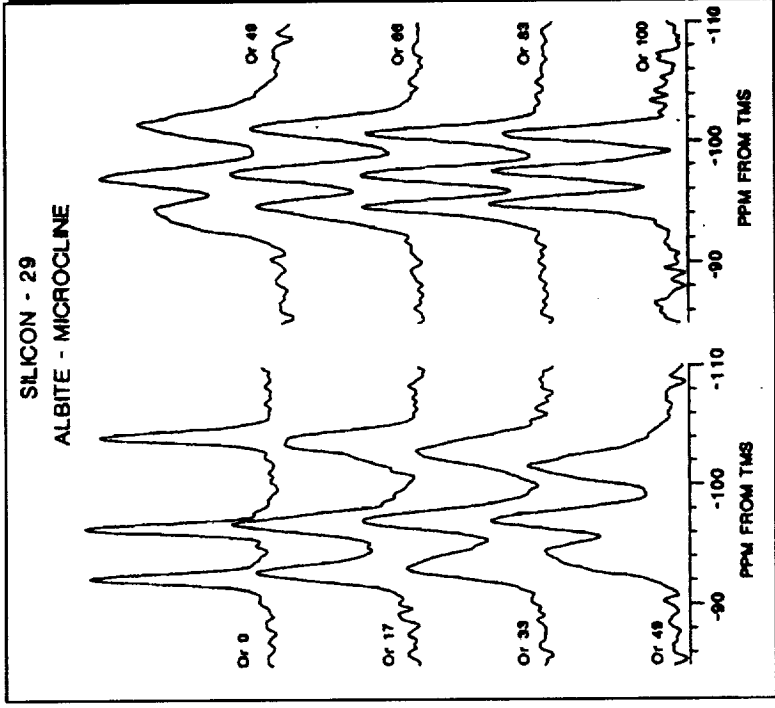
Nuclear Magnetic Resonance

Chemical shifts result from electronic shielding anisotropies, dipole-dipole interactions with nearby nuclei, and quadrupole moment interactions.



No field.

Applied magnetic field causes Zeeman splitting of energy levels.



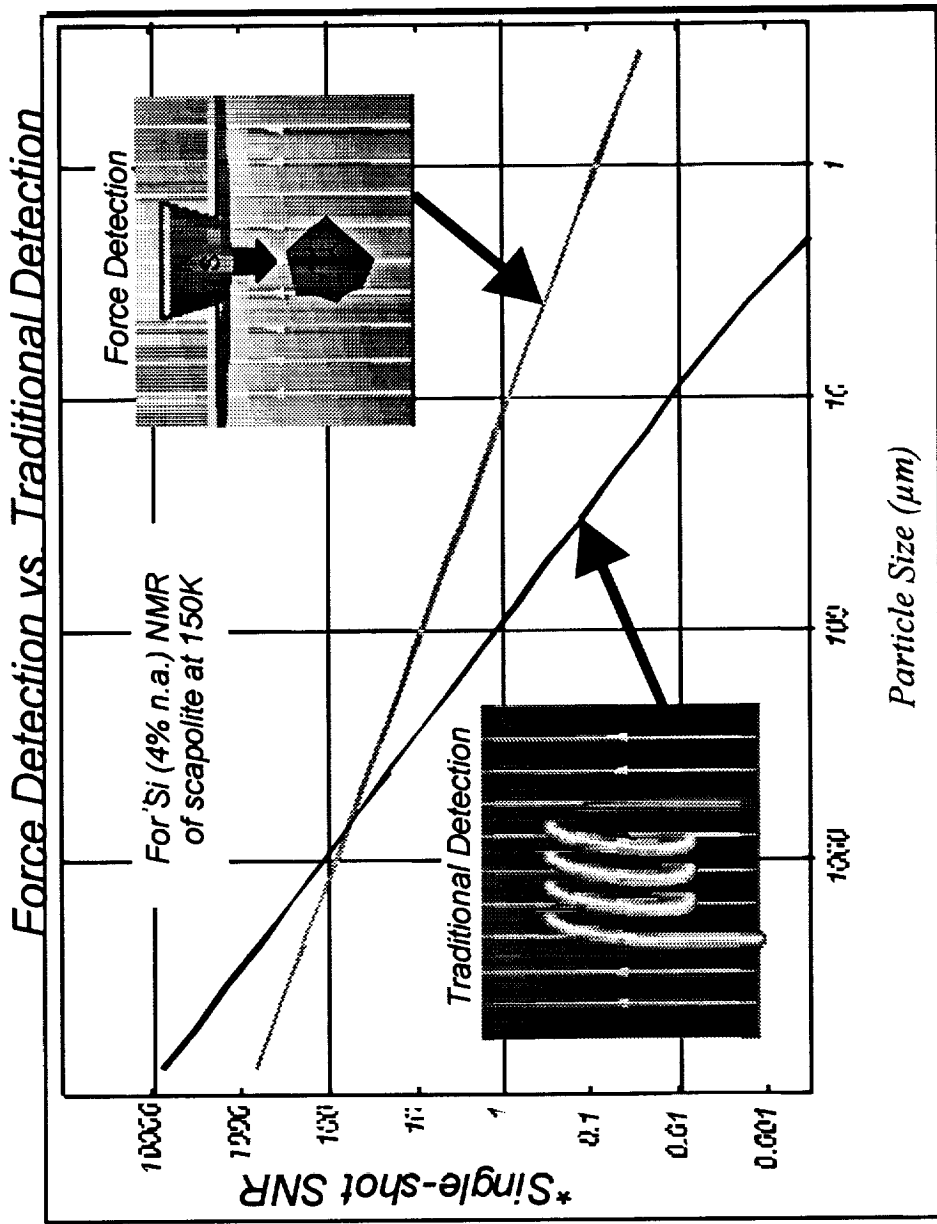
The three distinct ^{29}Si NMR lines of Si, Al ordered feldspars. The peaks correspond to the three types of Si sites.

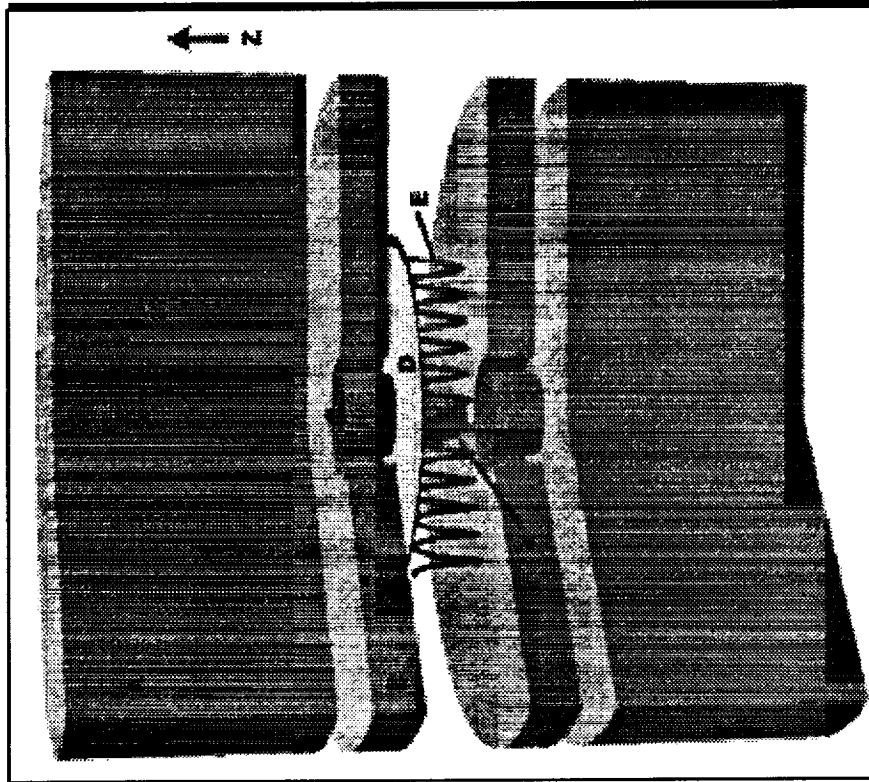
R. J. Kirkpatrick, Rev. in Miner. 18, 341 (1988).



Techniques

For sample sizes less than 1 mm, the Force Detection technique has a higher signal-to-noise Ratio than the conventional Inductive Detection technique





Ferromagnets (A, B, and C) provide a homogeneous magnetic field at the sample (F). The sensor magnet (C) is mounted on a membrane (D) to form a harmonic oscillator. The RF coil (E) allows for arbitrary NMR pulse sequences, including a period in which the longitudinal magnetization is cyclically inverted at the mechanical resonance frequency to drive the oscillator. A fiber optic interferometer (G) detects the oscillator amplitude.

Challenges

- Microfabrication of magnets and oscillators.
- Handling and locating of samples.
- Assembly and testing.