sensor. In the improved design, no attempt is made to use a conventional temperature sensor. Instead, for purposes of monitoring and feedback control of the temperature, the electrical resistance of the tube is measured as a function of time and the temperature is computed in real time by use of temperature-vs.-resistance data obtained in prior calibration measurements on the tube.

This work was done by Ernest Frederick Hasselbrink, Jr.; Patrick J. Hunt, and Richard D. Sacks of the University of Michigan for Goddard Space Flight Center.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

University of Michigan
2350 Hayward Street Room 2150
Ann Arbor, MI 48019

Refer to GSC-14855-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

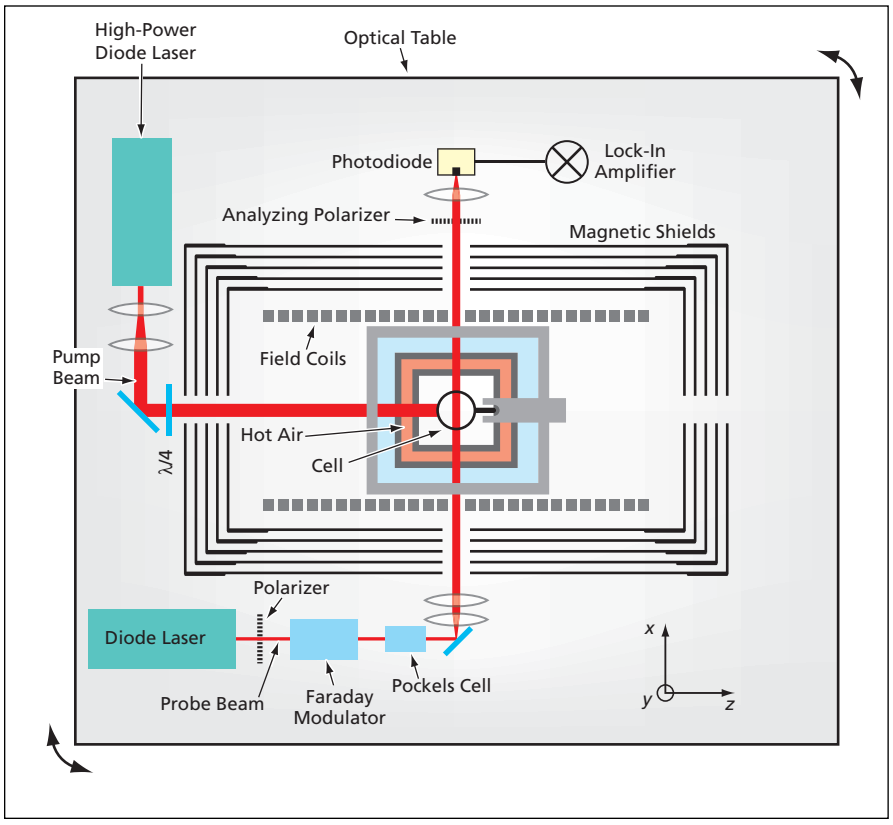
Nuclear-Spin Gyroscope Based on an Atomic Co-Magnetometer

Sensitivity to magnetic fields is eliminated.

John H. Glenn Research Center, Cleveland, Ohio

An experimental nuclear-spin gyroscope is based on an alkali-metal/noble-gas co-magnetometer, which automatically cancels the effects of magnetic fields. Whereas the performances of prior nuclear-spin gyroscopes are limited by sensitivity to magnetic fields, this gyroscope is insensitive to magnetic fields and to other external perturbations. In addition, relative to prior nuclear-spin gyroscopes, this one exhibits greater sensitivity to rotation. There is commercial interest in development of small, highly sensitive gyroscopes. The present experimental device could be a prototype for development of nuclear-spin gyroscopes suitable for navigation. In comparison with fiber-optic gyroscopes, these gyroscopes would draw less power and would be smaller, lighter, more sensitive, and less costly.

The co-magnetometer (see figure) includes a spherical aluminosilicate glass cell containing potassium vapor, several atmospheres of helium-3, and a small quantity of nitrogen (which serves as a buffer gas). The cell resides in a small oven, which is used to maintain the cell contents at a temperature of 170 °C. The oven is located within a housing that includes several layers of magnetic shielding.



This **Atomic Co-Magnetometer** generates an output signal proportional to the rate of rotation about the *y* axis.

Potassium atoms are polarized by optical pumping, and the polarization is transferred to the helium by spin-exchange collisions. A high-power diode laser generates the pump beam, which passes through holes in the magnetic-shielding layers and oven and through the cell along the *z* axis of an *xyz* Cartesian coordinate system. Another, lower-power diode laser generates a linearly polarized probe beam, which similarly passes through the cell along the *z* axis. The probe beam is used to measure the direction of polarization of the electrons in the potassium atoms, which is coupled to the nuclear polarization of the helium due to the imaginary part of the spin-exchange cross-section.

For sufficiently high buffer-gas pressure in a spherical cell, this coupling can be represented by an effective magnetic field that each spin species (K or He) experiences from the average magnetization of the other.

It has been shown that the relationships among the electron polarization of the potassium atoms, the nuclear polarization of the helium atoms, the magnetic fields, and the mechanical rotation of the magnetometer are described by a system of coupled Bloch equations. The equations have been solved to obtain an equation for (1) a compensating magnetic field, automatically generated in the magnetometer, that exactly cancels other magnetic fields; and (2) a gyroscope output signal that is proportional to the rate of mechanical rotation about the *y* axis and independent of magnetic fields. In experiments, the gyroscope-output equation has been verified to within a calibration error of 3 percent, and the expected insensitivity to rotation about the *x* and *z* axes was confirmed. In a future version, sensitivity could be increased by substitut-

ing ^{21}Ne for ^{3}He as the noble gas and increasing the sensitivity of optical measurement of rotation of polarization at low frequencies to approach the spin-projection noise.

This work was done by Michael Romalis, Tom Kornack, and Rajat Ghosh of Princeton University for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17942-1.

Utilizing Ion-Mobility Data To Estimate Molecular Masses

Potential applications include detecting biochemicals in pharmaceutical settings.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method is being developed for utilizing readings of an ion-mobility spectrometer (IMS) to estimate molecular masses of ions that have passed through the spectrometer. The method involves the use of (1) some feature-based descriptors of structures of molecules of interest and (2) reduced ion mobilities calculated from IMS readings as inputs to (3) a neural network. This development is part of a larger effort to enable the use of IMSs as relatively inexpensive, robust, lightweight instruments to identify, via molecular masses, individual compounds or groups of compounds (especially organic compounds) that may be present in specific environments or samples. Potential applications include detection of organic molecules as signs of life on remote planets, modeling and detection of biochemicals of interest in the pharmaceutical and agricultural industries, and detection of chemical and biological hazards in industrial, homeland-security, and industrial settings.

The following background information is prerequisite to a meaningful summary of the present method.

- An IMS includes a drift tube that has length L and is filled with a drift gas (e.g., N_2 or CO_2) at a pressure, P, which could be atmospheric or any other suitable pressure. Mixed into the drift gas is a trace amount of ionized molecules from a sample or environment of interest. An electric potential (V) is applied between the ends of the drift tube.
- The mobility (K) of the ions is given by $K \equiv L^2/Vt$, where t is the amount of time taken by the ions to drift along the tube from the inlet to a detector at the outlet.
- The correlation among the mobility, the mass (m) of an ion, the mass (M) of a drift-gas molecule, and the cross section (Ω) for collisions between an ion and a drift-gas molecule is given by

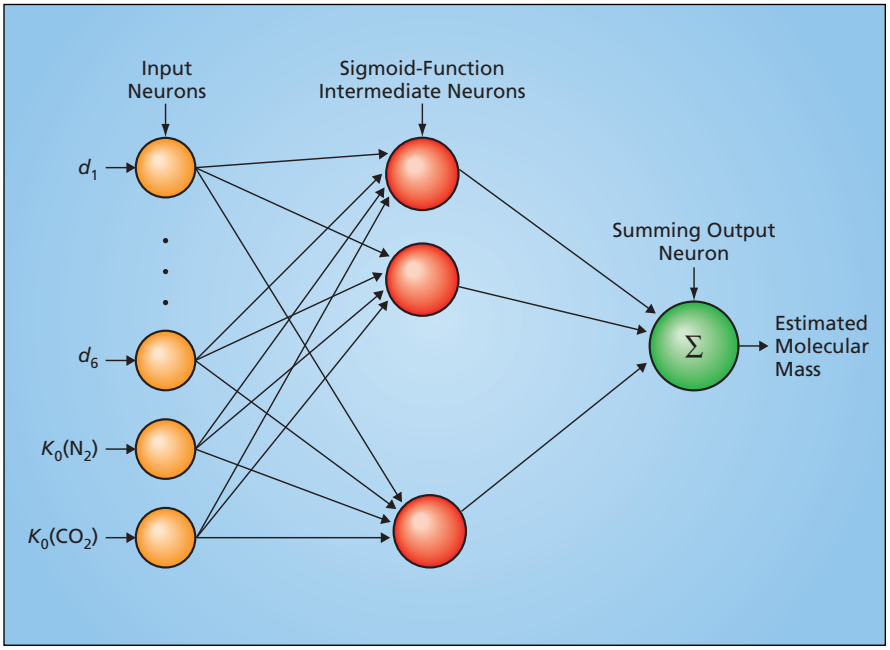
$$K = \frac{3q}{16N}\left(\frac{2\pi}{kT}\right)^{1/2}\left(\frac{m+M}{mM}\right)^{1/2}\frac{1}{\Omega}$$

where q is the fundamental unit of electric charge, N is the density of the drift-gas molecules, and k is Boltzmann's constant.

- The reduced mobility (K_0) is given by $K_0 \equiv KT_S P/TP_S$, where T_S denotes standard temperature (≈273 K) and P_S is standard atmospheric pressure (represented by a mercury-barometer column height of 760 mm under normal Earth gravitation).
- In a previous study, it was found that there are some correlations between the molecular structure of each compound and the K_0 value of ions of that compound in a given drift gas.

This concludes the background information.

The theoretical basis of the present developmental method can be summarized as the hypotheses that there could be a correlation among molecular structure, collision cross section, and molecular mass, such that it should be possible to estimate the mass of an ion by $m = \Phi(K_0)$, where Φ is a nonlinear function to be determined, $\hat{\Omega}$ is an estimated collision cross section that one strives to make as nearly equal as possible to the observed collision cross section. The estimated collision cross section is expressed as $\hat{\Omega} = g(W,S)$, g is another nonlinear function to be determined, W is a vector of weights in a parameter space (e.g., a vector of neural-network weights), and $S \equiv (d_1, d_2, d_3, ...)$ is a vector of feature-based numerical descriptors of the molecular structure. In this method, the applicable equations are not solved explicitly; rather, they are solved implicitly by means of a neural network (see figure). For each compound of interest, the inputs to the neural network are (1) a set of six feature-based descriptors extracted from a



A **Neural Network** processes six feature-based descriptors (d_1 through d_6) and reduced-mobility values for two drift gases [$K_0(N_2)$ and $K_0(N_2)$] into an estimate of molecular mass.