**A Technique for Adjusting Eigenfrequencies of WGM Resonators**

NASA’s Jet Propulsion Laboratory, Pasadena, California

A simple technique has been devised for making small, permanent changes in the eigenfrequencies (resonance frequencies) of whispering-gallery-mode (WGM) dielectric optical resonators that have high values of the resonance quality factor ($Q$). The essence of the technique is to coat the resonator with a thin layer of a transparent polymer having an index of refraction close to that of the resonator material. Successive small frequency adjustments can be made by applying successive coats. The technique was demonstrated on a calcium fluoride resonator to which successive coats of a polymer were applied by use of a hand-made wooden brush. To prevent temperature-related frequency shifts that could interfere with the verification of the effectiveness of this technique, the temperature of the resonator was stabilized by means of a three-stage thermoelectric cooler. Measurements of the resonator spectrum showed the frequency shifts caused by the successive coating layers.

This work was done by Dmitry Strekalov, Anatoliy Savchenkov, Lute Maleki, Andrey Matsko, Vladimir Iltchenko, and Jan Martin of Caltech for NASA’s Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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: Innovative Technology Assets Management JPL Mail Stop 202-233 4800 Oak Grove Drive Pasadena, CA 91109-8099 (818) 354-2240 E-mail: iaoffice@jpl.nasa.gov Refer to NPO-44383, volume and number of this NASA Tech Briefs issue, and the page number.

---

**Low-Pressure, Field-Ionizing Mass Spectrometer**

This lightweight, low-power instrument functions well in a low-grade (partial) vacuum.

NASA’s Jet Propulsion Laboratory, Pasadena, California

A small mass spectrometer utilizing a miniature field ionization source is now undergoing development. It is designed for use in a variety of applications in which there are requirements for a lightweight, low-power-consumption instrument that can analyze the masses of a wide variety of molecules and ions. The device can operate without need for a high-vacuum, carrier-gas feed radioactive ionizing source, or thermal ionizer. This mass spectrometer can operate either in the natural vacuum of outer space or on Earth at any ambient pressure below 50 torr (below about 6.7 kPa) — a partial vacuum that can easily be reached by use of a small sampling pump. This mass spectrometer also has a large dynamic range — from singly charged small gas ions to deoxyribonucleic acid (DNA) fragments larger than $10^4$ atomic mass units — with sensitivity adequate for detecting some molecules and ions at relative abundances of less than one part per billion.

This instrument (see figure) includes a field ionizer integrated with a rotating-field mass spectrometer (RFMS). The field ionizer effects ionization of a type characterized as “soft” in the art because it does not fragment molecules or initiate avalanche arcing. What makes the “soft” ionization mode possible is that the distance between the ionizing electrodes is less than mean free path for ions at the maximum anticipated operating voltage. Further information is contained in a TSP (see page 1).

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: Innovative Technology Assets Management JPL Mail Stop 202-233 4800 Oak Grove Drive Pasadena, CA 91109-8099 (818) 354-2240 E-mail: iaoffice@jpl.nasa.gov Refer to NPO-44383, volume and number of this NASA Tech Briefs issue, and the page number.
The field ionizer in this instrument is fabricated by micromachining a submicron-thick membrane out of an electrically nonconductive substrate, coating the membrane on both sides to form electrodes, then micromachining small holes through the electrodes and membrane. Because of the submicron electrode separation, even a potential of only 1 V applied between the electrodes gives rise to an electric field with a strength of in excess of a megavolt per meter — strong enough to ionize any gas molecules passing through the holes.

An accelerator grid and an electrostatic deflector focus the ions from the field ionizer into the rotating-field cell of the RFMS. The potentials applied to the electrodes of the cell to generate the rotating electric field typically range from 1 to 13 V. The ions travel in well-defined helices within this cell, after which they are collected in a Faraday cup. The mass of most of the molecules reaching the Faraday cup decreases with increasing frequency of rotation of the electric field in the cell. Therefore, the frequency of rotation of the electric field is made to vary in order to scan through a desired range of ion masses: For example, light-weight gas molecules are scanned at frequencies in the megahertz range, while DNA and other large organic molecules are scanned at kilohertz frequencies.

The current of accelerated ions is attenuated by collisions between these ions and the much slower (thermal) background gas molecules. In a typical case of operation at 5 Torr, an initial ion-beam current of about 10 nA would be attenuated to about 40 pA. However, the instrument could still afford adequate sensitivity because the electric current of ions collected by the Faraday cup is read by use of an electrometer that can resolve a current of the order of a femtoampere. In certain cases of low vacuum (10^{-5} Torr), a channel electron multiplier (CEM) plate could also be utilized in a single ion detection mode.

This work was done by Frank Hartley and Steven Smith of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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:

Innovative Technology Assets Management
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109-8099
(818) 354-2240
E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-30245, volume and number of this NASA Tech Briefs issue, and the page number.