



## Books & Reports

### Shock Waves in a Bose-Einstein Condensate

A paper presents a theoretical study of shock waves in a trapped Bose-Einstein condensate (BEC). The mathematical model of the BEC in this study is a nonlinear Schrödinger equation (NLSE) in which (1) the role of the wave function of a single particle in the traditional Schrödinger equation is played by a space- and time-dependent complex order parameter  $\psi(\mathbf{x}, t)$  proportional to the square root of the density of atoms and (2) the atoms engage in a repulsive interaction characterized by a potential proportional to  $|\psi(\mathbf{x}, t)|^2$ . Equations that describe macroscopic perturbations of the BEC at zero temperature are derived from the NLSE and simplifying assumptions are made, leading to equations for the propagation of sound waves and the transformation of sound waves into shock waves. Equations for the speeds of shock waves and the relationships between jumps of velocity and density across shock fronts are derived. Similarities and differences between this theory and the classical theory of sound waves and shocks in ordinary gases are noted. The present theory is illustrated by solving the equations for the example of a shock wave propagating in a cigar-shaped BEC.

*This work was done by Igor Kulikov and Michail Zak of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-30593*

### Progress on a Multichannel, Dual-Mixer Stability Analyzer

Several documents describe aspects of the continuing development of a multichannel, dual-mixer system for simultaneous characterization of the instabilities of multiple precise, low-noise oscillators. One of the documents presents the basic principles and design concept that were summarized in "Oscillator-Stability Analyzer Based on a Time-Tag Counter" (NPO-20749), *NASA Tech Briefs*, Vol. 25, No. 5 (May 2001), page 48. To recapitulate: One of the oscillators would be deemed to be a reference oscillator, its frequency would be offset by an amount (100 Hz) much greater than the desired data rate, and

each of the other oscillators would be compared with the frequency-offset signal by operation of a combination of hardware and software. A high-rate time-tag counter would collect zero-crossing times of the  $\approx 100$ -Hz beat notes. The system would effect a combination of interpolation and averaging to process the time tags into low-rate phase residuals at the desired grid times. Circuitry that has been developed since the cited prior article includes an eight-channel timer board to replace an obsolete commercial time-tag counter, plus a custom offset generator, cleanup loop, distribution amplifier, zero-crossing detector, and frequency divider.

*This work was done by Albert Kirk, Steven Cole, Gary Stevens, Blake Tucker, and Charles Greenhall of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-40468*

### Development of Carbon-Nanotube/Polymer Composites

A report presents a short discussion of one company's effort to develop composites of carbon nanotubes in epoxy and other polymer matrices. The focus of the discussion is on the desirability of chemically modifying carbon nanotubes to overcome their inherent chemical nonreactivity and thereby enable the formation of strong chemical bonds between nanotubes and epoxies (or other polymeric matrix materials or their monomeric precursors). The chemical modification is effected in a process in which discrete functional groups are covalently attached to the nanotube surfaces. The functionalization process was proposed by the company and demonstrated in practice for the first time during this development effort. The covalently attached functional groups are capable of reacting with the epoxy or other matrix resin to form covalent bonds. Furthermore, the company uses this process to chemically modify the nanotube surfaces, affording "tunable" adhesion to polymers and solubility in select solvents. Flat-sheet composites containing functionalized nanotubes demonstrate significantly improved mechanical, thermal, and electrical properties.

*This work was done by Thomas A. Reynolds of ReyTech Corp. for Johnson*

*Space Center. For further information, contact the Johnson Innovative Partnerships Office at (281) 483-3809. MSC-23428*

### Thermal Imaging of Earth for Accurate Pointing of Deep-Space Antennas

A report discusses a proposal to use thermal (long-wavelength infrared) images of the Earth, as seen from spacecraft at interplanetary distances, for pointing antennas and telescopes toward the Earth for Ka-band and optical communications. The purpose is to overcome two limitations of using visible images: (1) at large Earth phase angles, the light from the Earth is too faint; and (2) performance is degraded by large albedo variations associated with weather changes. In particular, it is proposed to use images in the wavelength band of 8 to 13  $\mu\text{m}$ , wherein the appearance of the Earth is substantially independent of the Earth phase angle and emissivity variations are small. The report addresses tracking requirements for optical and Ka-band communications, selection of the wavelength band, available signal level versus phase angle, background noise, and signal-to-noise ratio. Tracking errors are estimated for several conceptual systems employing currently available infrared image sensors. It is found that at Mars range, it should be possible to locate the centroid of the Earth image within a noise equivalent angle (a random angular error) between 10 and 150 nanoradians at a bias error of no more than 80 nanoradians.

*This work was done by Gerardo Ortiz and Shinhak Lee of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-40395*

### Modifications of a Composite-Material Combustion Chamber

Two short reports discuss modifications of a small, lightweight combustion chamber that comprises a carbon/carbon composite outer shell and an iridium/rhenium inner liner. The first report discusses chamber design modifications made as results of hot-fire tests and post-test characterization. The