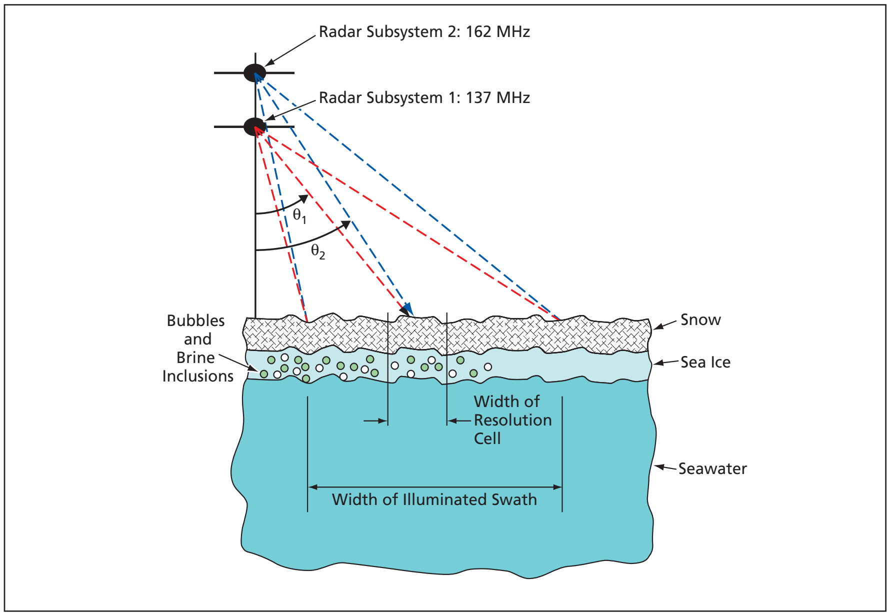
Interferometric System for Measuring Thickness of Sea Ice

Frequency- and spatial-domain VHF radar interferometry are used.

NASA's Jet Propulsion Laboratory, Pasadena, California

The cryospheric advanced sensor (CAS) is a developmental airborne (and, potentially, spaceborne) radar-based instrumentation system for measuring and mapping the thickness of sea ice. A planned future version of the system would also provide data on the thickness of snow covering sea ice. Frequent measurements of the thickness of polar ocean sea ice and its snow cover on a synoptic scale are critical to understanding global climate change and ocean circulation.

The CAS system includes two relatively-narrow-band chirped radar subsystems that operate about two different nominal middle frequencies in the very-high-frequency (VHF) range (e.g., 137 and 162 MHz). The radar targets the same surface area from two slightly different directions (see figure). The radar backscatter signals are processed to extract angular- and frequency-domain correlation functions (ACF/FCF) so that the system acts, in effect, as a combined spatial- and frequency-domain interferometric radar system.



Two Chirped VHF Radar Subsystems operating about different nominal middle frequencies targets the same surface area from two slightly different angles. Frequency- and spatial-domain interferometric computations performed on the radar backscatter signals enable determination of the thickness of the sea ice.

The phase of the ACF/FCF varies with the thickness of the sea ice. To enable the utilization of the phase information to compute this thickness, the interactions between the radar waves and the seawater, ice, and snow cover are represented by a mathematical model: The snow, sea ice (including air bubbles and brine inclusions), and seawater are represented as layers, each characterized by an assumed thickness and a known or assumed complex-number index of refraction. Each interface (air/snow, snow/ice, and ice/water) is modeled as deviating from a plane by a surface roughness characterized by a Gaussian spectrum. The scattering of the radar waves from the interfaces is computed by use of small-perturbation and Kirchhoff rough-surface submodels. The scattering from within the layers is computed by a Rayleigh volume scattering model. The ACF/FCF is computed from the scattered signals.

Assuming that the ACF/FCF obeys the model, the interferometric phase information can be inverted by use of a suitable computational inversion technique (e.g., a genetic algorithm or gradient descent or other least-squares technique) to obtain the thickness of the sea ice. In essence, the inversion amounts to seeking whichever value of sea-ice thickness used in the model yields the best match between (1) the ACF/FCF interferometric phase computed from the model and (2) the ACF/FCF measured interferometric phase.

This work was done by Ziad Hussein, Rolando Jordan, Kyle McDonald, Benjamin Holt, and John Huang of Caltech; Yasuo Kugo, Akira Ishimaru, and Sermsak Jaruwatanadilok of the University of Washington, Seattle; and Torry Akins and Prasad Gogineni of the University of Kansas, Lawrence, for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
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Microscale Regenerative Heat Exchanger

Materials and dimensions are chosen to optimize performance at microscale.

John H. Glenn Research Center, Cleveland, Ohio

The device illustrated in Figure 1 is designed primarily for use as a regenerative heat exchanger in a miniature Stirling engine or Stirling-cycle heat pump. A regenerative heat exchanger (sometimes called, simply, a "regenerator" in the Stirling-engine art) is basically a thermal capacitor: Its role in the Stirling cycle is to alternately accept heat from, then deliver heat to, an oscillating flow of a working fluid between compression and expansion volumes, without introducing an excessive pressure drop. These volumes are at different temperatures, and conduction of heat between these volumes is undesirable because it reduces the energy-conversion efficiency of the Stirling cycle. Hence, among the

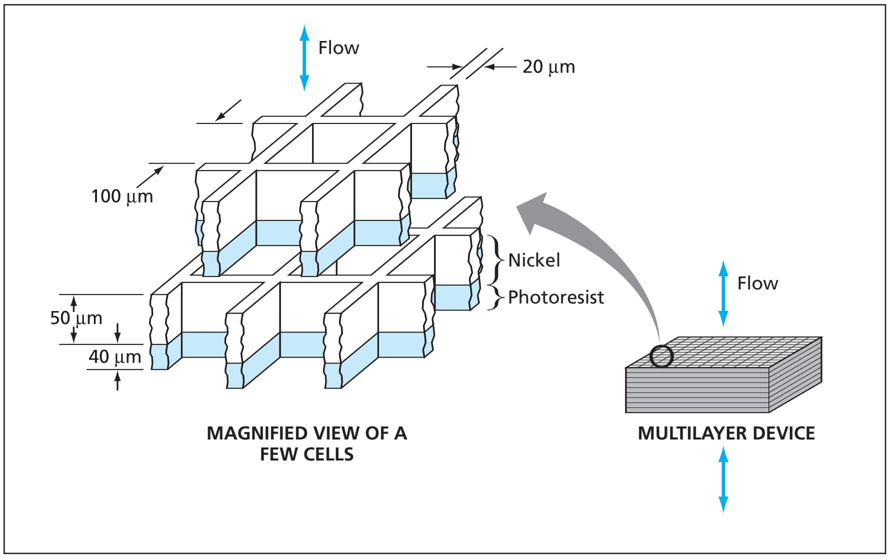

Figure 1. The **Configuration of This Device Is Typical** of a microscale heat exchanger as described in the text. The materials and dimensions shown here are representative rather than exclusive: they were chosen in a design trade study in which account was taken of capabilities for fabrication and of requirements for low axial thermal conduction and low pressure drop under a specific set of assumptions.

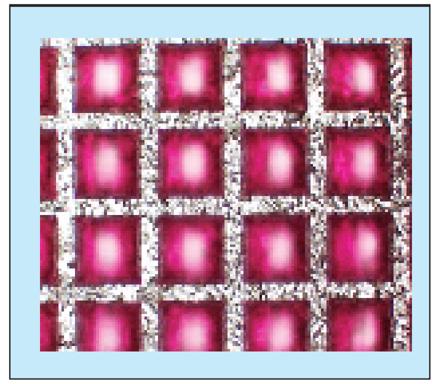

Figure 2. A **Microphotograph** of a portion of one layer of the fabricated microscale heat exchanger shows the grating structure and surface features of the nickel sublayer.

desired characteristics of a regenerative heat exchanger are low pressure drop and low thermal conductivity along the flow axis.

As shown in the enlarged views in Figure 1, the device features a multilayer grating structure in which each layer is offset from the adjacent layer by half a cell opening along both axes perpendicular to the flow axis. In addition, each grating layer is a composite of a high-thermal conductivity (in this case, nickel) sublayer (see Figure 2) and a low-thermal-conductivity (in this case, photoresist) sublayer. As a hot fluid flows through from, say, top to bottom, heat from the fluid is transferred to, and stored in, the cell walls of this device. Next, when cold fluid flows from bottom to top, heat is transferred from the cell walls to the fluid.

Axial thermal conduction in such a device can be minimized by constructing it of many layers containing low-thermal-conductivity sublayers. The offset of adjacent layers creates reduced-size, partially isolated cross sections for thermal conduction, thereby further reducing the overall axial thermal conductance of the device.

Once the device has been installed in its intended operational setting (e.g., as a regenerative heat exchanger in a Stirling machine), some delamination of the layers is permissible, provided that the half-cell offset between adjacent layers is maintained and no debris is produced. Indeed, delamination enhances performance by reducing axial thermal conduction.

The reasonably high porosity of the device helps to keep the pressure drop low. The layer-to-layer offset disrupts the formation of boundary layers in the flow, thereby contributing to the maintenance of low pressure drop. Disruption of boundary layers also increases the coefficient of transfer of heat between the fluid and the cell walls.

This work was done by Matthew E. Moran of **Glenn Research Center,** *and Stephan Stelter and Manfred Stelter of Polar Thermal Technologies. 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, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17526-1.