

Vacuum-Compatible Wideband White Light and Laser Combiner Source System

NASA's Jet Propulsion Laboratory, Pasadena, California

For the Space Interferometry Mission (SIM) Spectrum Calibration Development Unit (SCDU) testbed, wideband white light is used to simulate starlight. The white light source mount requires extremely stable pointing accuracy (<3.2 microradians). To meet this and other needs, the laser light from a single-mode fiber was combined, through a beam splitter window with special coating from broadband wavelengths, with light from multimode fiber. Both lights were coupled to a photonic crystal fiber (PCF).

In many optical systems, simulating a point star with broadband spectrum with stability of microradians for white light interferometry is a challenge. In this case, the cameras use the white light interference to balance two optical paths, and to maintain close tracking. In order

to coarse align the optical paths, a laser light is sent into the system to allow tracking of fringes because a narrow band laser has a great range of interference.

The design requirements forced the innovators to use a new type of optical fiber, and to take a large amount of care in aligning the input sources. The testbed required better than 1% throughput, or enough output power on the lowest spectrum to be detectable by the CCD camera (6 nW at camera). The system needed to be vacuum-compatible and to have the capability for combining a visible laser light at any time for calibration purposes.

The red laser is a commercially produced 635-nm laser 5-mW diode, and the white light source is a commercially produced tungsten halogen lamp that

gives a broad spectrum of about 525 to 800 nm full width at half maximum (FWHM), with about 1.4 mW of power at 630 nm. A custom-made beam splitter window with special coating for broadband wavelengths is used with the white light input via a 50-mm multi-mode fiber. The large mode area PCF is an LMA-8 made by Crystal Fibre (core diameter of 8.5 mm, mode field diameter of 6 mm, and numerical aperture at 625 nm of 0.083). Any science interferometer that needs a tracking laser fringe to assist in alignment can use this system.

This work was done by Alireza Azizi, Daniel J. Ryan, Hong Tang, Richard T. Demers, Hiroshi Kadogawa, Xin An, and George Y. Sun of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-46165

Optical Tapers as White-Light WGM Resonators

Such resonators could be attractive for broad-band optical processing applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

A theoretical analysis has revealed that tapered optical waveguides could be useful as white-light whispering-gallery-mode (WGM) optical resonators. The compactness and the fixed-narrow-frequency-band nature of the resonances of prior microdisk and microsphere WGM resonators are advantageous in low-power, fixed-narrow-frequency-band applications. However for optical-processing applications in which there are requirements for power levels higher and/or spectral responses broader than those of prior microdisk and microsphere WGM resonators, white-light WGM resonators in the form of optical tapers would be preferable.

In a typical prior microdisk or microsphere WGM resonator, the optical power is concentrated mostly in a small WGM volume, making it necessary to limit the power to a low level in order to minimize undesired nonlinear optical and thermo-optical effects. If one could construct a WGM resonator in which the optical power were spread over a larger volume, then the threshold power level for the onset of undesired nonlinear optical and thermo-optical effects would be higher.

The theoretical analysis was performed for a multimode, axisymmetric, circular-cross-section waveguide having a taper sufficiently smooth and gradual to justify the approximation of adiabaticity. In this approximation, the equation for the dependence of the electromagnetic field upon the axial (longitudinal) waveguide coordinate (z) can be separated from the equation for the dependence upon the radius (r) and the azimuthal angle (ϕ). Electromagnetic modes characterized by high angular momentum (equivalently, large values of the ϕ -dependence quantum number) were considered. The solution of the equation for the axial dependence was found to be an amplitude that varies gradually with z . For a given axial location z , where the outer surface of the waveguide has a radius $R(z)$, the solutions for the radial and azimuthal dependences were found to be WGM modes equivalent to those for a cylinder of radius $R(z)$.

In effect, it was found that the tapered waveguide can be considered to support WGMs propagating along the waveguide axis. It was further found that as the radius tapers down toward the classical

critical radius R_c at a classical turn-around axial position z_c , the group delay of a WGM increases and the electromagnetic field becomes increasingly concentrated, albeit in an effective mode volume typically much larger than the mode volume in a prior microdisk or microsphere WGM resonator. Thus, it was found that the power density of the electromagnetic field is much less than in a prior microdisk or microsphere WGM resonator and the onset of undesired nonlinearities is shifted to a significantly higher power level. It was found that in the special case of a linear taper, the turning point varies linearly with the frequency of the electromagnetic field, while the resonance quality factor and dispersion remain fixed to first order.

A resonator having these characteristics can be considered a white-light resonator in that it exhibits resonance over a continuous frequency range.

This work was done by Dmitry V. Strelakov and Andrey B. Matsko of Caltech and Anatoliy A. Savchenkov of OE Waves for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-45842