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Woodruff Scientific, Inc.
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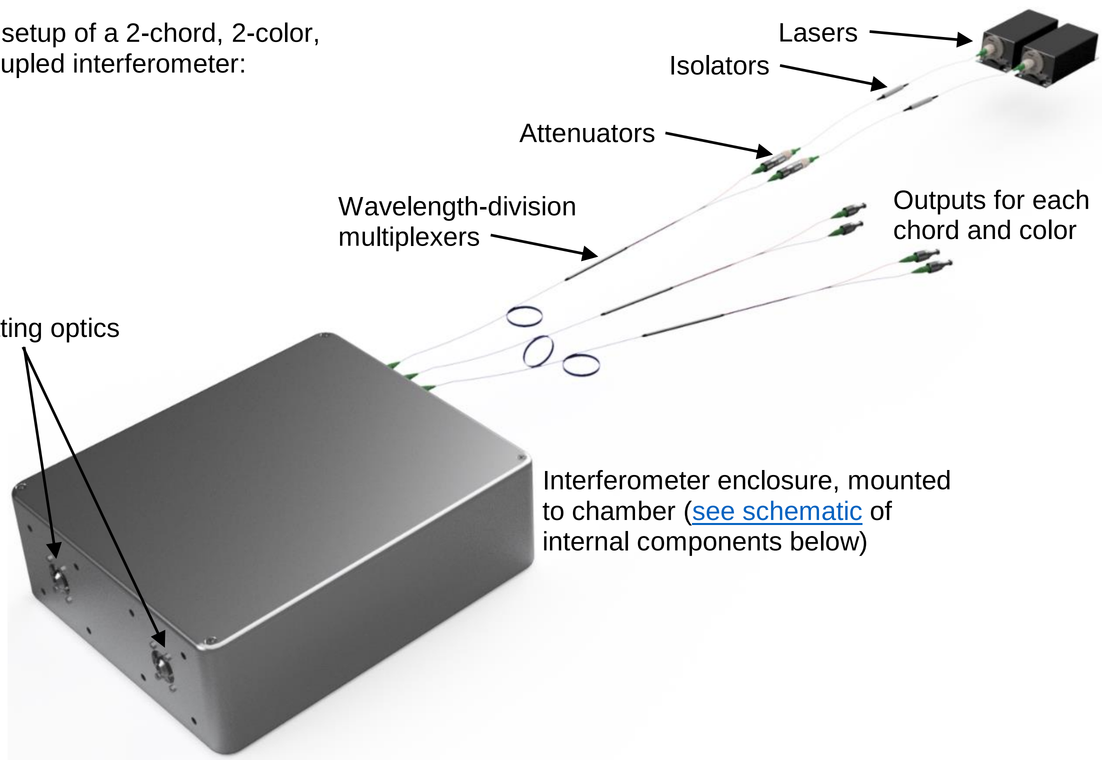
**http://www.woodruffscientific.com**

**Model number(s):** R1-F-2C
**Descriptive name:** Fiber-Coupled, 2-color Interferometer

Optical setup of a 2-chord, 2-color, fiber-coupled interferometer:




**Features:**

- Measures chord-averaged electron density using two laser wavelengths for vibration compensation
- Fiber-based design allows line of sight to be changed without realignment of optics
- High-frequency laser provides high temporal resolution
- Heterodyne configuration for extended unambiguous measurement range
- Extendable to multiple chords
- Custom mounting to vacuum chamber
- Laser sources in 1.31 µm and 1.55 µm wavelengths
- Uses FC/APC fiber optic connections for high quality beam launching
- Includes simple alignment system using fiber-coupled HeNe laser "seen beam"
- Class 3B lasers are housed in an interlocked enclosure with output attenuated to safe level

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**Operational ratings:**

| | |
|---|---|
| Electron density ($n_e$): | $< 5 \times 10^{26}$ m$^{-3}$ |
| Density resolution* ($\delta<n_eL>$): | $3 \times 10^{19}$ m$^{-2}$ |
| Temporal resolution** ($d<n_eL>/dt$): | $1 \times 10^{30}$ m$^{-2}$s$^{-1}$ |

** corresponding to 1.0° phase resolution; actual resolution may vary with application*

*** depending on data acquisition*

**Options:**

*Number of chords*
Having multiple chords allows for the spatial reconstruction of the electron density profile or analysis of plasma propagation, but increases the cost and complexity of the system.

WSI also offers a single-color, fiber-coupled interferometer, as well as standard HeNe, $CO_2$, and microwave interferometers. See the website for more information.

Contact WSI for pricing, operational ratings specific to your application, and more information on which options may be appropriate for you. Please provide any information you may have about your application's density, size, and timescale, as well as any preferences.

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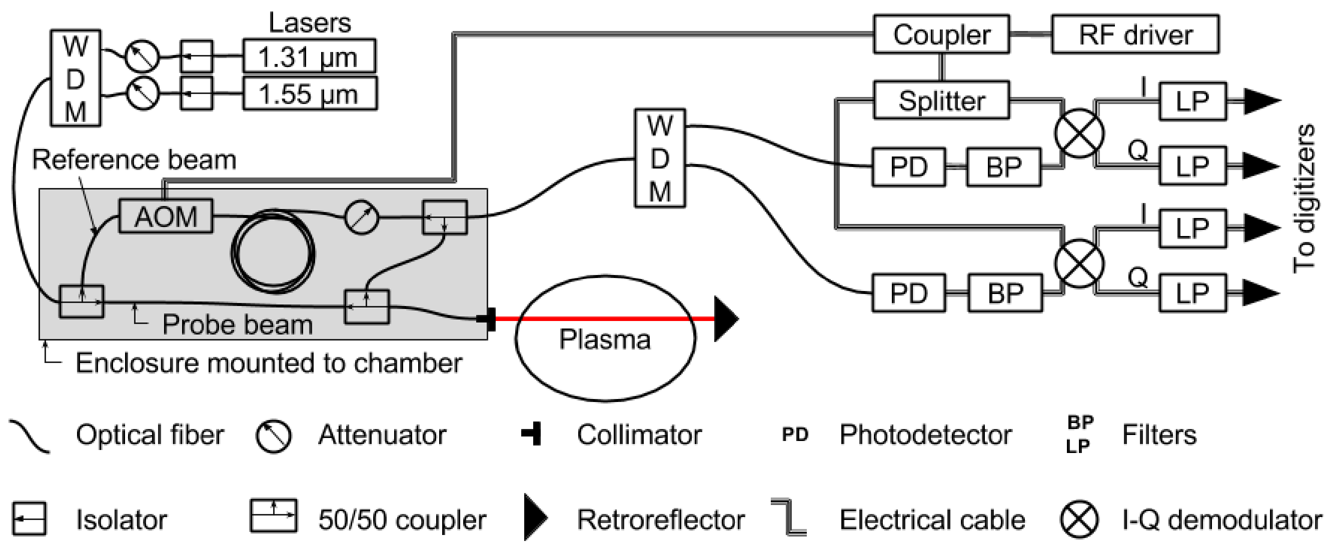
**Schematic (1-chord option shown):**




Shown above are the optical (left) and electrical (right) schematics for a 1-chord R1-F-2C interferometer. The fiber-coupled lasers are sent through isolators and attenuators to a wavelength-division multiplexer (WDM), which combines the two beams. The combined beam is then routed to an enclosure mounted to the vacuum chamber. The beam is divided by a 50/50 coupler into the probe and reference beams.

The reference beam is frequency shifted by an acousto-optic modulator (AOM), then send through a fiber delay and an attenuator. The probe beam goes backwards through another coupler, through a collimator and the plasma, is reflected, crosses the plasma again, and reenters the enclosure via the collimator. When the probe beam goes forwards through the coupler, half is sent back toward the lasers and is stopped by the isolators. The other half is sent to another coupler, where it is recombined with the reference beam.

The recombined beam is split into the two colors by another WDM. The two colors are separately converted to an electrical signal, filtered, and mixed with the RF driver signal. The I and Q for each color are output to coaxial cables for connection to the experiment DAQ system.

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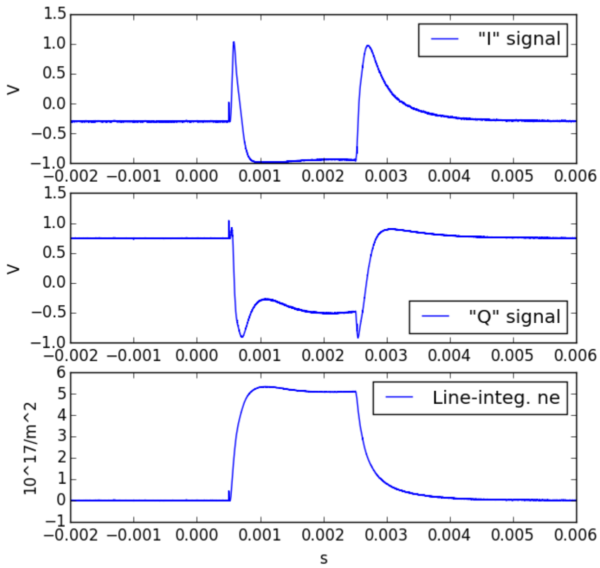
**Example data:**

At right is example data from an interferometer. The I and Q signals represent the cosine and sine of the phase shift, respectively. These values are used to unambiguously compute the phase shift for each color, $\Delta\varphi_i$. Both colors experience a phase shift due to the plasma and acoustic vibration, but the shorter wavelength is more sensitive to the vibration. Subtracting a portion of the shorter wavelength's phase shift from that of the longer wavelength allows the phase shift caused only by the plasma to be determined, as shown below. The line-integrated electron density, $\overline{n_e L}$, is calculated from the plasma-induced phase shift, and is shown in the bottom of the plot.




$$\Delta\varphi_i = \Delta\varphi_{plasma} + \Delta\varphi_{vibration} = k\lambda_i\overline{n_e L} + \frac{2\pi}{\lambda_i}\Delta L, \qquad k \equiv \frac{e^2}{2c^s m_e \varepsilon_0}$$

$$\Delta\varphi_{plasma} = \Delta\varphi_1 - \frac{\lambda_2}{\lambda_1}\Delta\varphi_2, \qquad \lambda_1 > \lambda_2$$

$$\overline{n_e L} = \frac{\lambda_1}{k(\lambda_1^2 - \lambda_2^2)}\left[\Delta\varphi_1 - \frac{\lambda_2}{\lambda_1}\Delta\varphi_2\right]$$

where, $e$ is the electron charge, $c$ is the speed of light, $m_e$ is the electron mass, and $\varepsilon_0$ is the vacuum permittivity.

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**Engineering drawing:**