"Lapped polarization-maintaining fiber resonator"

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The passive resonator approach to fiber optic rotation sensing has benefitted from recent advances in fiber components. High performance couplers, spliceless resonators[1], and long coherence length laser diodes have been described. Polarization maintaining components and 1.3 & 1.55 um wavelength components are being made, and one company is selling high finesse resonators commercially[2]. This paper describes lapped spliceless optically-contact-bonded resonators and their performance. These resonators have polarization crosstalk of < -20 dB and < 70 kHz linewidth with high modulation depth.

The resonators and couplers described herein are fabricated using a technique similar to the lapped block method developed by Bergh et. al[3]. Two lapped blocks on opposite ends of a single fiber make a spliceless resonator when coupled together. Elliptical stress member polarization-maintaining fiber that is optimized for 1.3 μm wavelength is used in all of the components discussed here. The selection of fiber type, fiber adhesive, lapping compound, and other factors are important to achieve high yield and performance.

The principal axes of the polarization-maintaining fiber are aligned to the surface of the blocks prior to bonding in the groove. Our setup can locate the principal axes accurately as demonstrated by couplers made with < -28 dB polarization cross-coupling between fibers. As the coupler halves are polished, successive oil drop tests[4] are performed to determine the distance between the fiber core and the polished surface.

When two coupler halves are polished to the proper distance from the core they are ready for mating, alignment, and bonding. Optical-contact-bonding, widely used in the attachment of ring laser gyro mirrors and other optical components, occurs when two similar surfaces are brought into intimate contact with one another. If surface flatness, roughness, and cleanliness are sufficient, Van der Waals forces draws the blocks together forming essentially one piece. This is an extremely rugged, hermetic bonding method which introduces no extra index layer between the two waveguides.

The two blocks are thoroughly cleaned and assembled into a specially designed optical contacting fixture, and a short length of the resonant loop is linear phase modulated by a removeable piezoelectric stretcher. A long coherence length gas laser and appropriate detection electronics allow monitoring of modulation depth and finesse while the blocks are aligned. The blocks are adjusted carefully to achieve optimum position; less than 0.1 dB change in coupling ratio is experienced going from the unbonded to bonded condition. When the performance of the coupler or resonator is sufficient, slight pressure on the blocks initiates the bonding process.

Table 1 describes the performance of two optically-contact-bonded spliceless resonators made at Honeywell, and two using index matching oil. Modulation depth is difficult to measure because the gas laser does not always emit a true single frequency output, which creates partition noise[5]. Reflections from fiber endfaces, if not minimized, will also create large unwanted amplitude fluctuations from the Fabry-Perot cavity created. The linewidth of the 1.523 μm wavelength gas laser is approximately 1 MHz, thus the coherence length is only about 20 times the resonant loop length. This could limit the maximum measured finesse and modulation depth[6] in a high finesse resonator. No active control of laser mode drift was attempted, so data could only be taken when the mode was centered on the laser's gain curve temporarily yielding single-mode operation. Polarization of the input light was carefully aligned to the fiber's principal axis, minimizing the unwanted orthogonal resonance dip[7]. A broadband source is used in lieu of the gas laser to provide stable polarization cross-coupling values[8]. Asymmetric mode loss differences are minimized due to the absence of an index-matching layer between the waveguides. This produces more symmetric resonance dips[9] which are important for some gyro demodulation schemes.

A typical plot of output intensity vs. phase is shown in figure 1, which is data from resonator R13-R14. Note the lack of Fabry-Perot ripple and othogonal polarization dips. A 10x expansion of a resonant dip is shown in figure 2 showing a high degree of symmetry. The coupling coefficent and loss are calculated to be approximately 0.98 and 0.01 respectively

In conclusion, high performance polarization-maintaining optically-contact-bonded spliceless resonators and couplers are routinely fabricated with high yields. Resonator/coupler assemblys have been fabricated using low backscatter (-60 dB) splices. Linewidths of 65 kHz have been achieved with 90% modulation depth having very low Fabry-Perot, orthogonal polarization, and asymmetric loss effects. Finesse and modulation depth may actually be higher than what is measured due to the limited source coherence length. Major difficulties are with gas laser spectral, amplitude noise, and reliability issues. DFB and other laser diodes and stabilized HeNe lasers are being investigated for improved sources. Better surface quality, finesse, dip symmetry and backscatter measurement systems are being investigated. There is room for much improvement in performance, as we have made low loss coupler halves with 35 dB polarization extinction ratio, and others have reported very high finesse values using standard (not P.M.) fiber.

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LIST OF FIGURE CAPTIONS

TABLE 1

Resonator no.	R1-R2	R5-R6	R11-R12	R13-R14	
Bond type	oil	oil	OC	OC	
Wavelength	1.523	1.523	1.523	1.523	um
Loop length	20	16	20	20	m
F. S. R.	10.3	12.8	10.3	10.3	MHz
Finesse	113	125	150	160	
Linewidth	91	103	69	65	kHz
Mod. depth	>98	>90	>87	>90	%
Pol. ext. ratio	>25	>26	>15	>22	dB
Orth. pol. dip	-	-	<-25	<-30	dB
Backscatter	Fresnel	reflection	<-60	<-80	dB
Fabry-Perot	10%	10%	<-30	<-30	dB

FIGURE 1

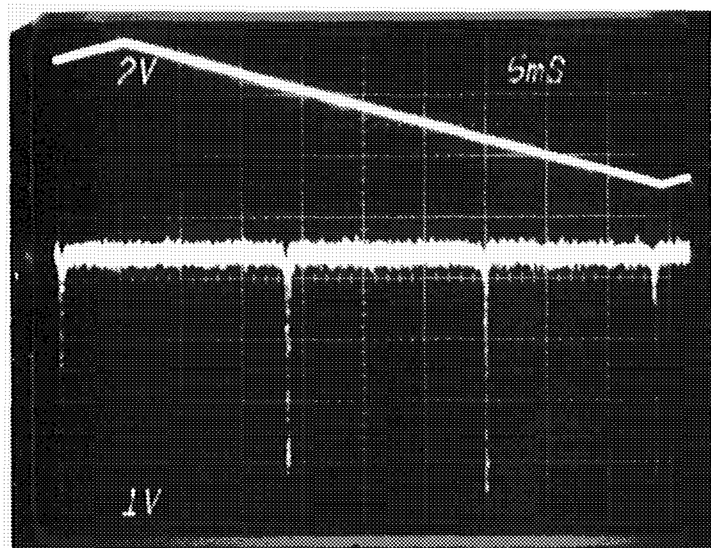

FIGURE 2