Rayleigh Backscattering in a Fiber Gyroscope with Limited Coherence Sources

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Abstract—Noise due to temporal fluctuations of Rayleigh backscattered light in fiber-optical gyroscopes is studied experimentally with various sources whose coherence length is less than the fiber length. The reduction of the coherent fraction of backscattered light and its fluctuation frequencies with reduced source coherence is demonstrated and fit to an analytical model. Measured backscatter parameters for the fiber and sources used are presented.

I. INTRODUCTION

The contributions to excess noise in a fiber-optical gyroscope by temporal fluctuations in Rayleigh backscattered light have been pointed out by Cutler et al. [1] and by Böhm et al. [2]. The backscattered signal varies in a random way in amplitude and phase, which causes an error signal to appear in the gyro output as a Sagnac phase shift. Although various approaches were suggested to alleviate this problem, we focus on only one here, the use of a low-coherence source. With the recent development of high-power low-divergence superluminescent diodes [3] that have short coherence lengths, this approach appears to offer great potential. As explained in the paper by Böhm et al. [2], the use of a low-coherence source greatly reduces the fraction of backscattered power which can interfere coherently thus reducing the magnitude of the error signal. Although the methods of the work by Böhm et al. [2] allow this magnitude to be calculated, since the gyro error is due to the random fluctuation of the error signal, we also require knowledge of the fluctuation frequencies at which the error signal varies. This information should ultimately allow prediction of gyro random walk drift [1] due to Rayleigh backscattering as a function of backscattering parameters and source coherence.

The statistics of backscattering in single-mode fibers have been studied by Eickhoff and Ulrich [4], [5] and noise due to multiple scattering by Eickhoff [6]. In this earlier work, backscattering fluctuations were set up by a controlled temperature variation of the fiber coil or change in the laser frequency, which results in a noise power spectrum with a predictable shape. In contrast, a fiber gyro coil is subject to random and varying environmental perturbations, due to temperature and acoustic fluctuations. This spectrum of perturbations will lead to a more complicated noise power spectrum which will be representative of the particular environment the coil is in. Clearly such a noise power spectrum, on which the ultimate gyro performance depends, is most readily accessible experimentally.

In this paper, we report on an experimental study of Rayleigh backscattering noise in a fiber gyro configuration (Fig. 1) using sources with coherence lengths shorter than the length of the fiber coil. A model is developed and experimentally confirmed to describe the coherence length dependence of the backscatter noise power in a fiber gyroscope. Experimental results are given for the noise power spectrum representative of typical environmental perturbations on the fiber coil and the coherence length dependence of the noise power spectrum is demonstrated. We also present measured backscatter parameters for the fibers and sources that we used.

II. THEORY

We consider a gyroscope configuration as in Fig. 1. A laser source is divided by a gyro beam splitter and, with shutters A and B open, power $I_0$ is fed into each end of the gyro fiber coil. A separate beam splitter is used to observe the backscatter signal $S(t)$, to avoid simultaneous observation of the gyroscopic signal. We will ignore beam splitter transmission and reflectivity factors. With shutters A and B open we observe the backscattered light plus $I_0$; with shutter A closed and shutter B open we observe the backscattered light alone. For the moment we will also ignore fiber-transmission factors and source coherence.

We assume fiber electric field inputs $E_0 e^{j\omega t}$ and a time-varying backscattered electric field $E_b(t)e^{j\omega(t)}$, where the amplitudes $E_0$ and $E_b(t)$ are real and $\omega$ is the source frequency. With shutters A and B open we observe the electric field

$$E(t) = E_0 e^{j\omega t} + E_b(t) e^{j\omega(t)}.$$  (1)

The observed intensity $S(t) = E(t)E^*(t)$ is

$$S(t) = I_0 + I_b(t) + 2 \sqrt{I_0 I_b(t)} \cos \{\phi(t) - \omega t\}$$  (2)

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where \( I_0 = E_0^2 \) and \( I_\theta(t) = E_\theta^2(t) \). The rms time average of (2) is

\[
\overline{S}_{rms} = I_0 + \overline{I}_b(t) + [2I_0\overline{I}_b(t)]^{1/2}
\]

(3)

where the overbar denotes time average. For \( \overline{I}_b \ll I_0 \), the time averaged noise term in (3) is

\[
\overline{I}_N = (2I_0\overline{I}_b)^{1/2}
\]

(4)

which shows that the backscattered noise power \( \overline{I}_b \) is amplified by \( I_0 \) in the gyroscope configuration of Fig. 1.

Next we calculate \( \overline{I}_b \), the time averaged backscatter power, and introduce source coherence. We will follow the notation of the paper by Böhm et al. [2]. We assume a fiber transmission \( T_0 = e^{-\alpha_tL} \), where \( \alpha_t \) is the total loss coefficient and \( L \) is the fiber coil length. We let \( \alpha_s \) be the loss coefficient due to scattering and \( S \) is the backward trapping factor or the fraction of total scattered power, which is captured by the backward traveling mode. Then from the paper by Lin and Giallorenzi [7], the backscattered power at the fiber end is given by

\[
\overline{I}_b = \alpha_s S I_0 \int e^{-2x\alpha_s} \, dx
\]

(5)

where \( x \) is a fiber length variable measured from the observation end and the integral is evaluated over the scattering length of interest.

The temporal fluctuations in backscattered light, which are considered in some detail in the paper by Eickhoff and Ulrich [4], are a consequence of the source coherence as well as fluctuations of propagation constant in the fiber. We note that (5), which is based on the scattering loss coefficient \( \alpha_s \), or Beer’s Law, assumes total incoherence in the source. Alternatively, with partially coherent sources, we may employ (5) by taking suitable time averages of backscattered intensity. To date the subject of coherence in Rayleigh backscattering has been treated in an ad hoc manner and we will do the same here. Böhm et al. [2] have pointed out that source coherence does not affect the total backscattered power, but rather affects the fraction of that power which can interfere. With shutter \( A \) closed in Fig. 1, the total time-averaged backscattered power is given by integrating (5) over the length of the fiber. The result is

\[
\overline{I}_b = \frac{\alpha_s S}{2\alpha_t} I_0 (1 - T_0^2).
\]

(6)

We define \( \overline{I}_{bc} \) as the time-averaged coherent fraction of backscattered power, which is capable of interference and causing time-varying components in the output. For this case (shutter \( A \) closed), the fraction of coherent backscatter is given by [2]

\[
\overline{I}_{bc} = \frac{L_c}{L} \overline{I}_b, \quad L_c \lesssim L
\]

(7)

where \( L_c \) is the source coherence length measured in the fiber and \( \overline{I}_b \) is given by (6). A completely incoherent source then creates backscatter which has no time-varying component. We rewrite (7) as

\[
\overline{I}_{bc}(ave) = \left( \frac{L_c}{L} \right) \frac{\alpha_s S}{2\alpha_t} I_0 (1 - T_0^2)
\]

(8)

where we emphasize that the coherent part of the backscatter sees attenuation averaged over the entire fiber length in this case.

The situation is somewhat different when shutter \( A \) is opened in Fig. 1 to provide a source field traveling with the backscatter. In this case, there will be interference between the backscatter and the codirectional source field only within a coherence length of the midpoint of the fiber [2]. Integrating (5) from \( (L - L_c)/2 \) to \( (L + L_c)/2 \) yields the coherent fraction of backscatter

\[
\overline{I}_{bc} \left( \frac{L}{2} \right) = \frac{\alpha_s S}{\alpha_t} I_0 T_0 \sinh (\alpha_t L_c), \quad L_c \lesssim L
\]

(9)

where we emphasize that this portion of backscatter arises from the midpoint of the fiber.

With shutter \( A \) open the noise term from (4) now becomes

\[
\overline{I}_n = (2I_0\overline{I}_b \overline{I}_{bc}(L/2))^{1/2}
\]

(10)

where we have reduced \( I_0 \) by the fiber-transmission factor \( T_0 \) and replaced \( \overline{I}_b \) by \( \overline{I}_{bc}(L/2) \). Then the time-averaged ratio of the noise with shutter \( A \) open to the noise with shutter \( A \) closed is given by

\[
\frac{\overline{I}_n}{\overline{I}_{bc}(ave)} = \frac{2T_0 L}{1 - T_0^2} \frac{L_c}{\alpha_t S} \left( \frac{2\alpha_t}{\alpha_t S} \sinh (\alpha_t L_c) \right)^{1/2} \quad L_c \lesssim L
\]

(11)

which depends on the coherence length of the source. Given the fiber loss and scattering parameters, the coherence length dependence of (11) can be tested experimentally.

Next we discuss the frequency of the temporal fluctuations in the backscattered power. We let \( \Omega \) be the fluctuation frequency and \( P(\Omega) \) the power spectral density of fluctuations. The total time-averaged backscatter power is then

\[
\overline{I}_b = \int P(\Omega) \, d\Omega
\]

(12)

and if we exclude the power at \( \Omega = 0 \) we obtain the coherent fraction of the backscatter

\[
\overline{I}_{bc} = \int_{\Omega > 0} P(\Omega) \, d\Omega.
\]

(13)

The temporal fluctuations of the backscattered light arise from time-varying fluctuations of the fiber propagation constant \( \beta \), which may be due to thermal or acoustic noise or to frequency fluctuations in the laser. The fluctuation frequency that arises from such a fluctuation in \( \beta \) is given by [4], [6]

\[
\Omega = 2\beta \Delta \lambda
\]

(14)

where \( \beta = d\beta/\,dt \) and \( \Delta \lambda \) is the separation of the two scattering centers from which backscattered light interferes to cause the fluctuation \( \Omega \). For \( L_c \gg L \), the maximum fluctuation frequency is determined by the fiber length for a given \( \beta \)

\[
\Omega_{max} = 2\beta L, \quad L_c \gg L
\]

(15)

For \( L_c \ll L \), the maximum fluctuation frequency is limited by the coherence length of the source. For a coherence length \( L_c \) we can imagine a coherent region of length \( L_c \) moving at a velocity \( L_c/\tau_c \), where \( \tau_c \) is the coherence time. As sketched in
The coherence length of the source can then be calculated from its initial position \( x_1 - L_c/2 \). This minimum value corresponds to a dc coherence length, \( \tau_c \approx L_c \). The time-averaged backscatter intensity can be obtained. With the HeNe laser the backscattered light showed rapid and large temporal fluctuations.

\[
\Omega_{\text{max}} = \beta L_c, \quad L_c \ll 2L.
\]

In our case, \( \beta \) will not be a constant, but will have some statistical distribution reflecting perturbations on the fiber and source.

Finally, we consider the temporal behavior of the backscatter, which, as we will see, can yield information on the coherence length of the source. For \( L_c \gg L \), the temporal behavior has been shown [4]. For \( L_c < L \) we expect to see temporal behavior as shown in Fig. 3. The time-averaged backscatter intensity is by definition \( I_b \). We also expect to see a well-defined minimum value of \( I_b(t) \), which is zero if \( L_c \gg L \), but nonzero if \( L_c < L \). This minimum value corresponds to a dc level which is the incoherent fraction of the backscatter. The coherent fraction \( I_{bc} \) then corresponds to the difference between the time average and the minimum value. Given the fiber length \( L \), the coherence length \( L_c \) can then be calculated from (7). This provides a direct experimental determination of the source coherence length from the temporal behavior of the backscatter.

Since our experiments involve the source coherence length, and we will want to independently determine this quantity from other measurements, we require an appropriate definition of coherence length. The coherence length of a source of bandwidth \( \Delta \nu \) in a media of index \( n \) is defined in terms of the coherence time \( \tau_c \) as

\[
L_c = \frac{c}{n \Delta \nu} = \tau_c.
\]

The coherence time can be estimated by two approaches [8]: the more common approach is to assume an idealized model of identical wavetrains of equal duration which yields the order of magnitude relation

\[
\tau_c \approx \frac{1}{\Delta \nu}.
\]

A more rigorous mathematical argument which defines \( \tau_c \) and \( \Delta \nu \) as suitable averages for real sources yields the inequality

\[
\tau_c \approx \frac{1}{4\pi \Delta \nu}.
\]

which for optical frequencies may also be considered an order of magnitude relationship. Since the coherence time is an imprecise quantity, we will use both (17) and (18) to provide a range for the coherence time and thus the coherence length.

### III. Experiment

We first measured the attenuation and scattering parameters for two ITT single-mode fibers with source wavelengths at 0.633 and 0.84 \( \mu \)m. The first fiber was single mode at 0.633 \( \mu \)m with a high attenuation of 26 dB/km. The second fiber was single mode at 0.84 \( \mu \)m with an attenuation of 4.1 dB/km. The known fiber parameters are given in Table I along with the fiber lengths on which the backscattering measurements were made. The sources used in these measurements were a Tropel single-mode HeNe laser and a low coherence superluminescent diode [3] (SLD) at 0.84 \( \mu \)m. After the attenuation coefficient \( \alpha_d \) was measured in a long fiber length, an appropriate length of each fiber was set up and the backscattered power was observed. With the SLD the backscattered power was essentially dc and the level simply read from a power meter. With the HeNe laser the backscattered power showed rapid and large temporal fluctuations and a time-averaged value was obtained.

### Table I

| Rayleigh Scattering Parameters for ITT Single-Mode Fibers |
|-----------------|-----------------|-------|
| \( \alpha_c \) (dB/km) | \( \alpha_5 \) (dB/km) | \( \alpha_8 \) (dB/km) |
| 603 \( \mu \)m; 4.6 m | 26 | 7.5 \( 10^{-3} \) | \~ 1.3 \( 10^{-3} \) | 5.8 |
| 84 \( \mu \)m; 96 m | 37 | 2.4 \( 10^{-3} \) | \~ 1.3 \( 10^{-3} \) | 1.9 |
| Low loss fiber a) | | | |
| 603 \( \mu \)m; 900 m | 5.4 | 7.0 \( 10^{-3} \) | double moded |
| 0.84 \( \mu \)m; 900 m | 4.1 | 1.5 \( 10^{-3} \) | 1.3 \( 10^{-3} \) | 1.2 |

a) single mode at 0.633; NA = 0.11

b) \( V(0.83 \mu m) = 2.16; NA = 0.11; \lambda_c = 0.75 \mu m \)
by using an integrating energy detector with a 10-s integration time. Knowing \( \alpha_t \) and the input and backscattered power levels, we calculated \( \alpha_S \) from (6). Then, for each single-mode case, we calculate \( S \) using the formulation of Brinkmeyer [9], and obtain the scattering coefficient \( \alpha_S \). The results are given in Table I. We note that the ratio of scattering coefficients for the high loss fiber which is single-mode at both wavelengths is in excellent agreement with the \( \lambda^{-4} \) Rayleigh scattering wavelength dependence. The actual scattering in the two fibers was quite similar, regardless of the large difference in total attenuation.

Next we observed the backscatter fluctuation frequency as a function of source coherence using the experimental arrangement of Fig. 1. Fluctuation frequencies were observed by frequency analyzing the backscattered signal with a Hewlett-Packard Model #3582A spectrum analyzer. In these experiments the source was decoupled from the gyro loop by using a Faraday isolator. Isolation achieved was 60 dB at 0.633 \( \mu \)m and \( \geq \)30 dB at 0.8 \( \mu \)m. This isolation is required to avoid feedback effects and resulting instabilities in the source from the Rayleigh backscattering [10].

In Fig. 4, we show the frequency analyzed backscattered signal, with various conditions of the shutters in Fig. 1, for an ordinary HeNe laser and the 900-m coil of low-loss ITT fiber. With both shutters open the laser is circulating in the coil in both directions (gyro configuration) and we observe backscatter plus the clockwise laser. With shutter \( A \) open and \( B \) closed only the clockwise laser is in the coil and we observe the intensity fluctuations in the source. With shutter \( A \) closed and \( B \) open only the counterclockwise laser is in the coil and we observe the backscatter from that signal, by itself. Also we show the detector (photomultiplier) noise level. We can observe the backscatter plus laser noise and the backscatter noise out to about 10-15 kHz, at which point the noise in the gyro configuration is limited by the laser noise and the backscatter noise is limited by the detector noise. In Fig. 4, we plot the relative noise in a 1-Hz bandwidth referenced to the clockwise laser power.

A typical temporal trace of the Rayleigh backscatter intensity in this case is shown in Fig. 5 and a histogram of 400 intensity values is shown in Fig. 6. The backscatter intensity has a minimum value \( (I_{\text{min}}) \) at \( I = 5 \), which we attribute to limited coherence. In the absence of coherent reflections we would expect the intensity distribution to decay exponentially from the minimum value of intensity [4]. The histogram shows a maximum which is offset from the minimum intensity value, indicating the presence of some reflected power from the focusing lens and fiber end face, although these effects were carefully minimized. We note that an exponential distribution can be satisfactorily fitted to the histogram on the high intensity side of the maximum. Ignoring the deviation of the distribution from the theoretical exponential, we calculate an average value \( I_D = 19.5 \). Then, from Fig. 3, we have \( I_{bc} = I_D - I_{\text{min}} = 14.5 \), and with a fiber length of 900 m, we have from (7) a source coherence length for the HeNe Laser of 670 m in the fiber. We estimate that this number could be in error due to coherent reflections by 10-20 percent.

In Fig. 7, we show similar data to Fig. 4 except that the HeNe source has been replaced by a Hitachi CSP 1400 laser diode at 0.81 \( \mu \)m. This laser had a measured linewidth of 14 MHz at 1.2 times threshold [10, 11] which from (16)-(18), corresponds to a coherence length between 1.2 and 15 m in the fiber. The fiber loop was the same 900 m of low-loss fiber used above. In Fig. 7 we show the noise in \( 10^{-3} \) of the clockwise laser (shutter \( A \) transmission \( 10^{-3} \), \( B \) closed), the backscatter noise (\( A \) closed, \( B \) open), the backscatter plus \( 10^{-3} \) of
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**Fig. 7.** Fluctuation spectrum of backscatter signal $S(t)$ with Hitachi laser diode source. Shutter conditions refer to Fig. 1. In this case the noise in $10^{-5}$ of the laser is larger than the backscatter noise and only slight amplification of the backscatter can be observed before the amplified noise is lost in the laser noise. Noise levels are relative to the clockwise laser signal and are normalized to a 1-Hz bandwidth.

Experimental bandwidth was 0.145 Hz.

**Fig. 8.** Fluctuation spectrum of backscatter signal with SLD source. This trace is totally detector noise limited and no backscatter fluctuations were observable. Noise levels are relative to the clockwise source and are normalized to a 1-Hz bandwidth. Experimental bandwidth was 0.0145 Hz.

the clockwise laser ($A$ transmission $10^{-5}$, $B$ open), and the detector (Si p-i-n diode) noise. The first difference we note between Figs. 4 and 7 is the large difference in fluctuation frequency as implied by (16). Second, we note that with the laser diode source the backscatter noise is smaller than the noise in $10^{-3}$ of the laser (Fig. 7), whereas in Fig. 4 the backscatter noise was larger than the total laser noise at frequencies below 5 kHz. As a consequence with the laser diode source we were only able to amplify the backscatter noise with $10^{-5}$ of the clockwise laser without losing the amplified backscatter noise in the laser noise. In Fig. 7 we plot the relative noise in a 1-Hz bandwidth referenced to the clockwise laser power.

Finally, we investigated backscatter fluctuations with a SLD at 0.84 mm. This source had a bandwidth of 14.7 mm and, from (16) and (17), an upper limit for the coherence length of 33 mm in the fiber. The fiber used was the 96-mm length of high-loss fiber. In Fig. 8 we show our attempt to observe fluctuations in the backscattered power from this source with the spectrum analyzer. The recorded noise power spectrum was entirely detector (Si p-i-n diode) noise limited and we were unable to observe any backscatter fluctuations whatsoever, down to frequencies below 0.1 Hz. In Fig. 8, the relative noise is again referenced to the clockaise source intensity, in a 1-Hz bandwidth.

**IV. DISCUSSION**

Figs. 4 and 7 show the power spectral density for backscatter fluctuations, and the amplification of the backscatter spectral density by the clockwise laser in a gyro configuration, for two different source coherence lengths. In each case we observe that the amplified backscatter noise, or gyro noise, has a power spectral density with a similar shape to the power spectral density of the backscatter itself. This follows from (2) where the temporal behavior of $S(t)$ is dominated by the temporal behavior of the backscatter intensity $I_{bc}(t)$. The influence of the backscatter phase $\phi(t)$ is lost in the term $\cos(\phi(t) - \omega t)$ due to the very high optical frequency $\omega$.

In order to employ (11) we need to relate the total time-averaged noise powers to the time-averaged spectral densities for the gyro and backscatter cases. From (13) we write for the backscatter noise

$$I_{bc}(\text{ave}) = \int_{\Omega>0} P_{bc}(\Omega) \, d\Omega$$

and for the gyro noise

$$I_n = \int_{\Omega>0} P_n(\Omega) \, d\Omega.$$  

From the observation just made about similar shapes of $\tilde{P}(\Omega)$ in each case we have

$$P_{bc}(\Omega) = \frac{P_{bc}}{\Omega} \tilde{P}(\Omega)$$

$$P_n(\Omega) = \frac{P_n}{\Omega} \tilde{f}(\Omega)$$

where $P_{bc}$ and $P_n$ are constants and $\tilde{f}(\Omega)$ is a time-averaged spectral shape. Substituting (20) into (19) and taking the ratio yields

$$\frac{I_n}{I_{bc}(\text{ave})} = \frac{P_n}{P_{bc}}.$$  

The ratio $P_n/P_{bc}$ is available experimentally from Figs. 4 and 7.

So far we have assumed equal intensities circulating in each direction through the loop in Fig. 1. If instead we assume an intensity $I_{cw}$ in the clockwise direction and $I_{ccw}$ in the counterclockwise direction, and combine (11) and (21), we obtain

$$\frac{P_n}{P_{bc}} = \left( \frac{2T_0L}{(1 - T_0^2)L_c} \left( \frac{2\alpha_L I_{cw}}{\alpha_S I_{ccw}} \sinh \left( \alpha_L L_c \right) \right) \right)^{1/2}. $$

Equation (22) can now be employed to compare our experiments with the theory developed in Section II.

From Fig. 4 the average separation between the gyro spectral density and the backscatter spectral density is $33 \text{ dB} \cdot \text{V}$ (between 0 and 13 kHz, at which point the signals are noise limited). The experimental ratio $I_{cw}/I_{ccw}$ was 1.79. Using the fiber parameters from Table I for the 900-mm length of low-loss fiber at 0.633 mm and the source coherence length of 670 m...
obtained in Section III, we calculate from (22) a spectral density separation of $20 \log \left( \frac{P_n}{P_b} \right) = 33.4 \text{ dB} \cdot \text{Hz}$, in good agreement with the experimental observation. We note, however, that with the coherence length just slightly less than the fiber length, this calculation is not especially sensitive to the value of $L_c$ chosen. Taking $L_c = L$ in (22) yields a spectral density separation of $32.8 \text{ dB} \cdot \text{Hz}$, giving equally good agreement with experiment. The existence of a nonzero $I_{\text{min}}$ in Fig. 6 does however imply $L_c < L$ in this experiment.

In Fig. 7, we obtain experimentally a spectral density separation of $\approx 15 \text{ dB} \cdot \text{Hz}$ (between 0 and 2 Hz, at which point the signals are noise limited) for an intensity ratio $I_{\text{cw}}/I_{\text{SW}} = 2.25 \times 10^{-5}$. Using the fiber parameters from Table I for the 900-m length of low-loss fiber at 0.8 $\mu$m, we calculate from (22) a corresponding source coherence length of 3.2 m. This value gives reasonable order of magnitude agreement to the range 1.2–15 m estimated in Section III from the measured laser bandwidth. In this case we could not estimate the coherence length from the temporal fluctuation of the backscatter, as we did with the HeNe source, as the observed fluctuation ($\approx 1$ percent) was too small to be quantitatively measured.

Our inability to observe any Rayleigh backscattering fluctuations with the SLD can be explained from coherence length considerations. The fraction of coherent backscatter power to total backscatter power is given by (7) as $L_c/L$. For the HeNe laser this is 74 percent, for the laser diode 0.4 percent and for the SLD ($L = 96 \text{ m}$), $< 10^{-4}$ percent. The maximum fluctuation frequency from (16) is also proportional to the coherence length. With the laser diode we could observe fluctuations above detector noise to $\sim 2$ Hz. With the SLD coherence length some 5 order of magnitude below that of the laser diode, we would expect the maximum observable fluctuation frequency to be $\sim 10^{-5}$ Hz, if the fraction of coherent backscattered power was unchanged. However, as discussed above, the fraction of coherent backscattered power is also reduced by the ratio of the coherence lengths, so that the maximum fluctuation frequency would be reduced even further. At the least we could say, for observation times short compared to a day, that the SLD backscatter would have a high probability of appearing dc, without any observable fluctuations whatsoever. In the opposite limit of long observation times a more involved calculation is required to estimate the impact of the SLD fluctuation spectrum on gyro performance.

**V. CONCLUSIONS**

We have developed a model that describes the coherence length dependence of the backscatter noise power in a fiber gyroscope. Experimental results are given for the noise power spectrum representative of laboratory perturbations on the gyro fiber coil and the coherence length dependence of the noise power spectrum was demonstrated for several sources. We have, in particular, provided results that demonstrate the reduction of both the coherent fraction of backscattered power and the fluctuation frequencies with reduced source coherence length. Although we do not provide a complete calculation here, this information should ultimately aid in the prediction of gyro random walk drift due to Rayleigh backscattering as a function of backscattering parameters and source coherence. Such a calculation will be useful to fiber-optic gyro designers.

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**REFERENCES**


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