EFFECT OF ORTHOGONAL-MODE RANDOM COUPLING ON POLARIZATION CHARACTERISTICS OF SINGLE-MODE FIBER LIGHTGUIDES (SMFL) AND SMFL-BASED RING INTERFEROMETERS. PART III. ZERO DRIFT IN RING INTERFEROMETERS WITH NONMONOCHROMATIC-RADIATION DEPOLARIZERS

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A method is proposed for calculation of the zero drift and Fedding interference signal at the output of a fiber ring interferometer with a circuit made of a weakly anisotropic single-mode fiber lightguide (SMFL) and a depolarizer made of an anisotropic SMFL with a nonmonochromatic radiation source. The fiber is divided into sections equal to the depolarization length in the SMFL. Four FRI circuits all of whose parameters are the same with the exception of the location of the depolarizer are compared theoretically for the first time. Numerical estimates are made. It is shown that an FRI with a Lyot depolarizer located between the polarizer and the circuit is best from a practical point of view. The required precision of assembly of the elements of the Lyot depolarizer is considerably lower than that in the other FRI circuits.

In Part II, it was shown that zero drift in a fiber ring interferometer (FRI) with a circuit made of a weakly anisotropic single-mode fiber lightguide (SMFL) is on the order of tens of degrees per hour even when the FRI has a high-quality polarizer with an amplitude extinction factor \( e = 10^{-3} \) and a broadband radiation source with spectral width \( \Delta \lambda = 10 \) nm, which is a result of considerable orthogonal-mode coupling in the weakly anisotropic SMFL. Note that despite the fact that an FRI with an anisotropic SMFL provides a substantially smaller zero drift [1, 2], a considerable number of FRIs are today made of weakly anisotropic SMFLs, since it is technically very difficult to create all-fiber FRIs based on anisotropic SMFLs.

Zero drift in an FRI with a weakly anisotropic SMFL is reduced by the use of nonmonochromatic-radiation depolarizers: a simple depolarizer consisting of a single segment of an anisotropic SMFL or a more-complicated Lyot depolarizer [3, 4] made up of two segments of an anisotropic SMFL in a 1:2 length ratio welded together at a 45° angle. Various depolarizer locations have been proposed: in front of the polarizer [5], between the polarizer and the circuit [6-8], and in the circuit itself, near the input splitter [9, 10]. It has been suggested [11] that the depolarizer be installed in the middle of the FRI circuit (note that a Billings monochromatic-radiation depolarizer [4] was examined in [11]). It has been shown [7, 8] that a depolarizer reduces zero drift in an FRI, other conditions being equal, by a factor of \( (h_{\text{dep}})^{1/2} \) where \( h \) is the random orthogonal-mode coupling parameter \( (m^{-1}) \) and \( l_{\text{dep}} = \lambda^2/\Delta \lambda \Delta n \) is the depolarization length in the SMFL of which the depolarizer is made (\( \lambda \) is the wavelength of the radiation source, \( \Delta \lambda \) is its spectral width, and \( \Delta n \) is the refractive-index difference for the SMFL orthogonal modes).

It has been shown [12] that for anisotropic SMFLs for which \( h_{\text{dep}} << 1 \), the limiting degree of polarization \( p \) of radiation propagated through a sufficiently long SMFL section is \( (h_{\text{dep}})^{1/2} \); thus, the depolarizer reduces zero drift in the FRI in inverse proportion to the residual degree of polarization in the fiber from which it is fabricated. Burns and Moeller [13, 14] have obtained at the depolarizer output a very low degree of polarization, \( p = (4 \pm 2) \cdot 10^{-4} \), which theoretically reduces zero drift in the FRI by a factor of \( 2.5 \cdot 10^{3} \).
Fig. 1. Four possible depolarizer locations: 1) in front of polarizer; 2) between polarizer and circuit; 3) within circuit, near input splitter; 4) in middle of circuit.

It has been shown [8] that when a Lyot depolarizer is installed between the polarizer and FRI circuit, it not only reduces zero drift but also greatly reduces the Fedding intensities of the interference signal (desired signal) at the FRI output, which, as was indicated in Part II, can be considerable.

At the same time, the zero drifts and desired-signal variations of FRIs with identical parameters that differ only in the depolarizer location have not been compared theoretically or experimentally in the literature. From general considerations, it can only be concluded that when the depolarizer is located ahead of the polarizer, it can in no way result in stabilization of the desired signal. It should be noted that corresponding calculations by the "quasi-axis" method [8] are rather time-consuming for the case of depolarizer location within the FRI circuit.

We shall compare the effect of a depolarizer on zero drift in an FRI and stabilization of the desired signal for various locations in the FRI by means of methods developed in Parts I and II, that is, by numerical modeling. In accordance with the conclusions of Part I, the depolarizer length was made such that its phase delay exceeded the phase delay in the FRI circuit, and, therefore, polarization could not be restored in the FRI.

The mathematical expectations of the zero shift $\bar{\Omega}$ and desired-signal intensity $\bar{I}$, their standard deviations $\sigma_{\Omega}$ and $\sigma_{I}$, and their maximum and minimum values $\Omega_{\text{max}}$, $\Omega_{\text{min}}$, $I_{\text{max}}$, and $I_{\text{min}}$ were calculated for four depolarizer locations: 1) in front of polarizer; 2) between polarizer and circuit; 3) within circuit, near input splitter; and 4) in middle of circuit. The following parameter values were selected: radiation with $\lambda = 0.8 \mu m$ and $\Delta \lambda = 10 \text{ nm}$, polarizer with $\varepsilon = 10^{-3}$, circuit of length $L = 500 \text{ m}$ of weakly anisotropic SMFL with $\Delta n_2 = 10^{-6}$ and $h_2 = 10^{-2} \text{ m}^{-1}$ ($l_{\text{dep2}} = 64 \text{ m}$, $h_{2l_{\text{dep2}}} = 0.64$), circuit diameter $D = 10 \text{ cm}$, and depolarizer of anisotropic SMFL with $\Delta n_1 = 3 \cdot 10^{-4}$ and $h_1 = 5 \cdot 10^{-5} \text{ m}^{-1}$ ($l_{\text{dep1}} = 20 \text{ cm}$, $h_{1l_{\text{dep1}}} = 10^{-5}$). Since for the circuit $N_2 = L/l_{\text{dep2}} = 500 \text{ m}/64 \text{ m} = 8$, in accordance with the conclusions of Part I the depolarizer length was made $12l_{\text{dep1}} = 2.4 \text{ m}$ for the simple depolarizer and $(12 + 24)l_{\text{dep1}} = 7.2 \text{ m}$ for the Lyot depolarizer.

In view of the fact that adjustment of the polarization state at the input of an FRI with a depolarizer is somewhat more complicated than in an FRI without a depolarizer, we assume the following polarization state at the FRI input: $S_1 = 0.925$, $(S_2^2 + S_3^2)^{1/2} = 0.4$ (4% of the total radiation intensity is perpendicular to the transmission axis of the polarizer).

Since in Scheme 1 the depolarizer is located ahead of the polarizer and cannot affect the Fedding desired signal, there is no fundamental difference between the effects of FRI operation of a simple depolarizer and a Lyot depolarizer if one of the anisotropy axes of the former coincides with the transmission direction of the polarizer. Therefore, the calculations were performed for a simple depolarizer for Scheme 1 and for a Lyot depolarizer for Schemes 2, 3, and 4.

The results of numerical modeling are presented in Table 1. As was to be expected, the mean zero drift $\bar{\Omega} = 0$, and its maximum possible deviations $\Delta \Omega$ are symmetrical with respect to zero for all FRI schemes. Note that our calculation results