

FIBER OPTIC GYRO IN-LINE TECHNOLOGY

V.Logozinski, N.Glavatskih, FIZOPTIKA Co., PO box 16, 109387, Moscow Russia

1. SUMMARY

The features of in-line technology for fiber optic gyro and other fiber optic sensors are described and demonstrated with complete gyro prototypes. For special fiber "fusion-tapering" technique has been modified to be universal and applicable for manufacturing of all fiber optic components from one fiber length. Thus considerable reduction of FOG manufacturing time is obtained.

2. INTRODUCTION

The main points of gyro development are known to be: gyro dimensions and weight; sensitivity and bias behavior; resistance to perturbations (temperature, shocks, vibration); scale factor stability, power consumption. The quality of "open-loop" gyro optics is related mainly to the first three points, as the electronics condition to the last one. Now the requirements to optical scheme and fiber components are developed. FOG optical architecture and market situation give many opportunities for the choice of the components. For gyro production it's also necessary to take into account economical factors (component prices, manufacturing time consumption etc.). These factors show that better to have all components (including basic - fiber, light source) production in house. The second approximation is to fabricate all special components (coupler, polarizer, module) in house. In this case it's also easy to meet different requirements for optics occurring with various gyro applications.

3. BASIC TECHNOLOGY CONCEPT

Operation of main gyro components (coupler, polarizer) is based on interaction of guided wave with anisotropic media or with another wave. So the first step of component fabrication is the access to guided wave. There are some techniques for access to wave guided by fiber - the removing of cladding (etching, polishing) or fiber tapering that transforms at some length core wave into cladding wave. We have chosen tapering technique as the most simple and easily controlled though it implies some known restrictions on fiber characteristics. However these demands do not conflict with other ones in fiber manufacturing. We use high frequency high voltage stabilized discharge for fiber heating. The heating element position control provides an opportunity to vary easily the temperature and a heating length to reach optimum parameters of the tapering process. Moreover, the weak dependence of the waist surface optical field strength on the fiber elongation makes it possible to achieve required characteristics of the components. When starting components fabrication with standard diameter (125 μ) fiber we recognized that the use of fiber with such diameter results not only in large size of components but also in problems with miniature gyro assembling and life time insurance. So, the general requirements for fiber adaptation for in-line gyro tapering technology are as follows: small cladding diameter; high aperture; matched refraction index profile; high birefringence.

We use specially developed by our order fiber with following parameters: cladding diameter 40 μ ; aperture > 0.2; beat length 3 - 5 mm.

4. OPTICAL COMPONENTS

Open-loop FOG optics is a set of components with following features related to optics quality: Coil and Modulator - optical loss, polarization maintenance; Coupler - optical loss, polarization selectivity, coupling ratio; POLARIZER - optical loss, extinction ratio; Light module - coupling efficiency, spectral width, matching to fiber cutoff, and general - resistance to environmental. In this section there is description of how we meet component's requirements with above fiber and our technique.

4.1. Fiber sensing coil

| REQUIREMENTS | REALIZATION | RESULTS |
|-------------------------------------------|-------------------------------------------------|-----------------------------------|
| Maintenance of polarization, optical loss | Winding under tension control, coating material | No optical parameters degradation |
| Vibration, temperature low sensitivity | Quadruple winding (depends on req.) | |

4.2. PZT - modulator

| | | |
|----------------------------------------|-------------------------------------------------|------------------------------------------------------|
| Low amplitude modulation [1,2] | Tension control, choice of fixing material | -90--100 dB |
| Low phase modulation at even harmonics | Choice of fixing material and modulator's shape | -80 - 100 dB with respect to 1-st harmonic amplitude |

Comments:

Demands to fixing arising from the above points are to some extent opposite. To prevent H-parameter degradation fixing has to be soft. From other side too soft fixing creates conditions for fiber to oscillate with respect to PZT surface as respective acceleration may reach 100g-200g under high oscillation frequency. It's clear that any fiber oscillation except pure elongation (radial PZT mode) changes fiber length at second(even) harmonics. These effects don not improve the bias behavior and has to be prevented by (for instance) strong fixing to PZT surface. So special fixing materials and PZT surface preparation are required.

4.3. Coupler

| | | | |
|-------------------------|-----------|--------------------------------------------------|--------------------------------------------------------------|
| Low optical loss | | Heating length adjustment | 0.5-1 dB |
| Small size | | ---"----- | |
| Polarization preserving | | | 80 - 90 % |
| Coupling ratio | | Output power or interference contrast monitoring | 1:1 tolerance 10% |
| Temperature sensitivity | Vibration | low | Tension control while soldering resonance freq. up to 20 kHz |

Comments:

With appropriate heating length it's possible to make coupler with weak local coupling. In this case for high birefringent fiber residual non synchronism does not permit differently polarized waves to couple. So fiber birefringence axis alignment may be omitted.

4.4. POLARIZER

Here we describe new type of fiber optic in-line polarizer. Concept -birefringent crystal cladding of tapered fiber. For tapered fiber the waist is a new core. So an evident solution for polarizer fabrication is to surround this core by birefringent media. For good behavior under environmental it has to be a rigid optical crystal with appropriate refractive indices. We have found out a set of appropriate materials which may be grown as from solution and from melting and all of them can be used for polarizer fabrication. Our investigation has shown better quality (related to the polarizer quality) and lower time consumption for the crystals grown from melting with respect to the ones grown from solutions because of better optical contact crystal and fiber. Good temperature behavior of polarizer in this case is guaranteed by high temperature of growing (up to 800°C-900°C). This fact has determined our choice of growing technique. Extinction ratio of such a polarizer depends on the optical field strength at the waist - crystal boundary (local attenuation) and crystal size. These parameters are controlled by tapering and growing techniques. So extinction ratio is controlled in the range from zero to some limiting value. This value for birefringent fiber is determined by taper quality (adiabatic) as the waist is not a monomode structure and also by orientation of crystal axes with respect to fiber axes. Optical loss also depends on taper quality and on waist diameter near the crystal (as the input may be the abrupt transition for the guided wave). Nevertheless requirements for FOG polarizer is not so strong if it's position with respect to coupler and light source are correctly chosen [3]. In our case it means that it is not necessary to align fiber and polarizer axes. So this procedure is also omitted.

| | | | |
|----------------------------------------|--|-----------------------------------------------|-----------------------------|
| High extinction ratio | | Waist diameter, Crystal size, Material choice | 40dB - 60dB |
| Low loss | | -----"----- | 1dB - 1.5dB |
| Vibration, temperature low sensitivity | | Tension control, Fixing material | resonance freq.up to 15 kHz |

4.5. Light module.

Requirements (brightness, wavelength, spectral width) are mainly fulfilled by the choice of the light emitting crystal [5, 6]. As for module itself, it's successful operation depends also on accuracy of alignment SLD and fiber and rigidity and stability of fixing material. Now it is recognized that one of the best solution is to use soldering technique for module fabrication. Coupling efficiency is determined by SLD waveguide structure and fiber aperture. Waveguide of high NA fiber may be almost matched to SLD one. Microlens at fiber end can not improve coupling efficiency in this case and associated procedure is sometimes removed from FOG manufacturing process.

5. EQUIPMENT

To realize the above technology procedures we have developed and designed the following equipment: winding unit with tension control and fiber distributor (quadruple winding is possible); fusion and tapering unit; crystal growing unit; fiber to light-chip alignment and soldering unit.

6. GYRO OPTICS MANUFACTURING

The sequence of the fiber element's fabrication procedures is shown on fig.1. As the fiber axes alignment and splicing are not present the remaining procedures are following: winding the coil and modulator, tapering of fiber in three points, fixing and crystal growing, SLD-chip to fiber soldering. After all optics assembling is performed without problems as the fiber diameter is small and the fiber is very flexible. From every beginning for component's characteristics monitoring we use one output fiber port as shown on fig.1. At every stage of the process optical losses, coupling ratio, extinction ratio, coupling efficiency may be measured through this port by signal spectrum analyzer.

ANALYZING BIAS DEPENDENCE. To control manufacturing process and to obtain closed-loop technology it's necessary to distinguish the sources of bias occurring due to components imperfections. The character of bias may be specified through it's dependence on phase modulation amplitude: as for optical bias (low extinction ratio, SLD to fiber mismatching) this dependence is J1(M), M-modulation depth; as for amplitude modulation (H-parameter degradation at PZT) - this is linear dependence; nonlinear phase modulation (slight coupling with modulator)-there is approx. as

J2(M) dependence. Moreover it's possible to use their different behavior under changing of temperature. For example, two different sources of bias are displayed at the gyro output dependence on temperature (Fig.2,3).

7. ELECTRONICS

For base electronics our initial requirements were: simplicity, low power consumption; modulation depth and scale factor stabilization; detection of first harmonic nonsensitive to the presence of even harmonics; correspondence of PZT exiting signal to optics quality. To meet them the analog electronics contains three control loops [4]. To enhance the phase modulation quality the frequency of the exiting signal is maintained at PZT resonance thus using it's mechanical filtering properties. This hybrid with some adjustment maintains scale factor with accuracy 3-5% (0.1-0.2% per C) in temperature range without correction and it's output dynamics corresponds to optics dynamics. The hybrid's power consumption is less then 1.5 W.

8. FOG PROTOTYPES

Now there are several gyro prototypes under development and production in our company. Whole production circle from fiber piece and SLD - chip to complete gyro takes now 8-10 hours. Here we describe characteristics of two gyros VG911 (one of the smallest complete gyro) and VG915. These types differ one from another only in design and TEC availability. Another gyro (with only one coupler) type VG912 also produced by Fizoptika Co. was described in Ref.4.

9. CONCLUSIONS

For middle and low performance gyro in-line technology gives a great reduction of GYRO manufacturing time and makes it possible to start with large scale production.

10. ACKNOWLEDGMENTS

The most of Fizoptika employees supported this work. Our special thanks go to Dr.A.Novikov for his activity in electronics development and design.

11. REFERENCES

1. J.Blake, J.Feth, J.Cox, P.Goettche "Design and test of a production open loop all-fiber gyroscope", proc.SPIE,1169,337(1989)
2. E.Kiesel "Accuracy limits of fiber gyroscopes due to modulation effect", Symp.Gyro Tech.,Stuttgart, 1987, Symp.Proc.,P 2.0.
3. E.Jones, J.Parker "Bias reduction by polarization dispersion on the fibre optic gyroscope",El.Lett.,22,55(1986)
4. V.Logozinski, A.Semenov "Small size simple configuration fiber optic gyro", Proc.SPIE,1585,paper 1585-52(1991)
5. K.Petermann "Intensity dependent nonreciprocal phase shift in fiber optic gyroscopes for light sources with low coherence", Opt.lett., 7, 623 (1982)
6. A.Semenov,B.Elenkrig and V.Logozinski "Universal Light Source for Optical Fiber Sensors", Proc.SPIE,1584,paper 1584-42(1991)