

Introduction/Executive Summary

The use of birefringent optical materials (*e.g.* YVO₄, TiO₂, LiNbO₃, etc.) in passive telecommunications components is becoming widespread. Numerous components including optical isolators, optical switches, interleavers, modulators, and multiplexers/demultiplexers now utilize these materials. Isomet has over 40 years experience working with birefringent materials, and we have recently begun to offer design, prototyping, and manufacturing of components based on these materials. We can also develop prototype components based on our acousto-optic technology.

Birefringent materials offer several advantages over other technologies employed in passive components:

- Passive temperature compensation is possible by using two different birefringent materials in combination.
- Passive losses of devices based on birefringent materials are typically low.
- Growth, fabrication, and anti-reflection coating of birefringent crystals is well developed.
- The cost of birefringent crystals used in passive components (*e.g.* YVO₄) has dropped significantly over the last 6 months.
- Devices such as demultiplexers/de-interleavers can be used in reverse as multiplexers/interleavers.
- For wavelength-filtering applications, tunability can be easily achieved.

As an example of our prototyping capability, we designed and built the Isomet Demultiplexer, which was operating at our NFOEC 2001 booth. This device included a single wavelength-filtering element and passive temperature compensation, which makes its performance insensitive to ambient temperature variation. The device passband can be easily tuned to match the ITU grid. It has a single-fiber input and a two-fiber output. Since the show, we have built a second-generation Isomet Demultiplexer that includes three wavelength-filtering elements and passive temperature compensation, which produces a flatter passband than the device we showed at NFOEC. As it is currently configured, the Demultiplexer can be used in two different modes. First, if the input fiber contains two channels separated by 100 GHz, it can be used as a demultiplexer in which each channel is coupled to a separate fiber. Second, if the input fiber contains a plurality of channels (for example 6), the device can function as a de-interleaver with the three “odd” frequency channels coupled to one fiber and the three “even” frequency channels coupled to the second fiber. Thus, when operating as a de-interleaver, the device converts a single 100 GHz channel stream to two 200 GHz channel streams. Note that the device can be operated in reverse as a multiplexer or interleaver. To enhance the versatility of the device, a user-controlled polarization rotator could be added that would allow operation as a wavelength router in which the output fibers for the “even” and “odd” frequencies could be interchanged.

The Demultiplexer is an example of Isomet’s ability to design and fabricate prototype passive components based on birefringent materials. Due to our extensive experience with birefringent materials and vertical integration (*i.e.* crystal growth, fabrication,

dicing, anti-reflection coating, mathematical modeling, optical/mechanical design, optical testing), we can quickly and cost effectively produce prototype components. This capability allows our customers to reduce significantly both development time and cost for new products. In addition, Isomet can process cost effectively birefringent materials and sub-components in high volume; for example, we have supplied >1200 polished, anti-reflection coated wafers (typically 0.1% per surface at 1550 nm) per month. For companies interested in design and rapid prototyping of passive components (*e.g.* interleavers, multiplexers, wavelength routers, gain flattening filters, polarization mode dispersion compensators, dynamic gain equalizers, and chromatic dispersion compensators) Isomet is your best choice! The following sections describe our thermal-compensation technology and the second-generation Isomet Demultiplexer in more detail.

Thermal-Compensation Technology

One of the most critical requirements for de-interleavers and demultiplexers (and other passive filtering components) is frequency stability over the required 0 to 70°C operating range. The temperature drift of the wavelength-filtering elements can be compensated with a second crystal. One of the most commonly used birefringent materials is YVO₄, and Figure 1 shows the wavelength drift of a single filtering element over the 24 to 67°C temperature range without (purple) and over the 12-105°C temperature range with (blue) a second temperature-compensating birefringent crystal. Figure 2 shows only the temperature-compensated case with an expanded Y-axis scale.

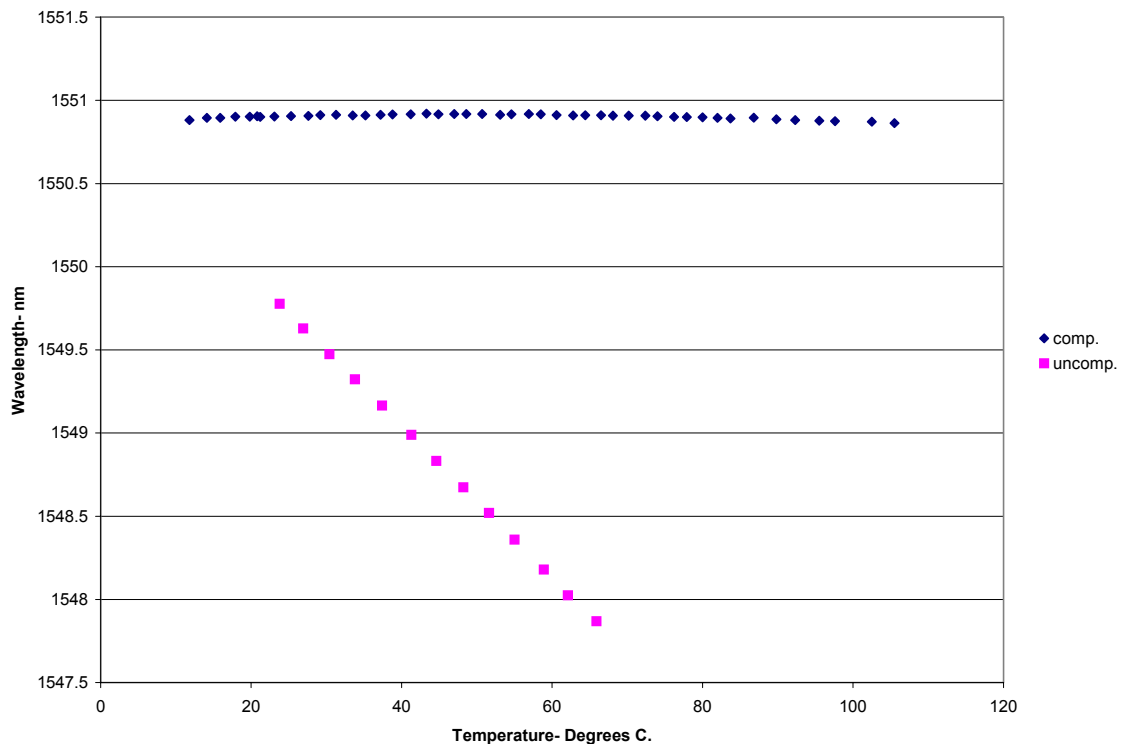


Figure 1. Wavelength drift of a single YVO₄ filtering element without (purple) and with (blue) a temperature-compensating crystal.

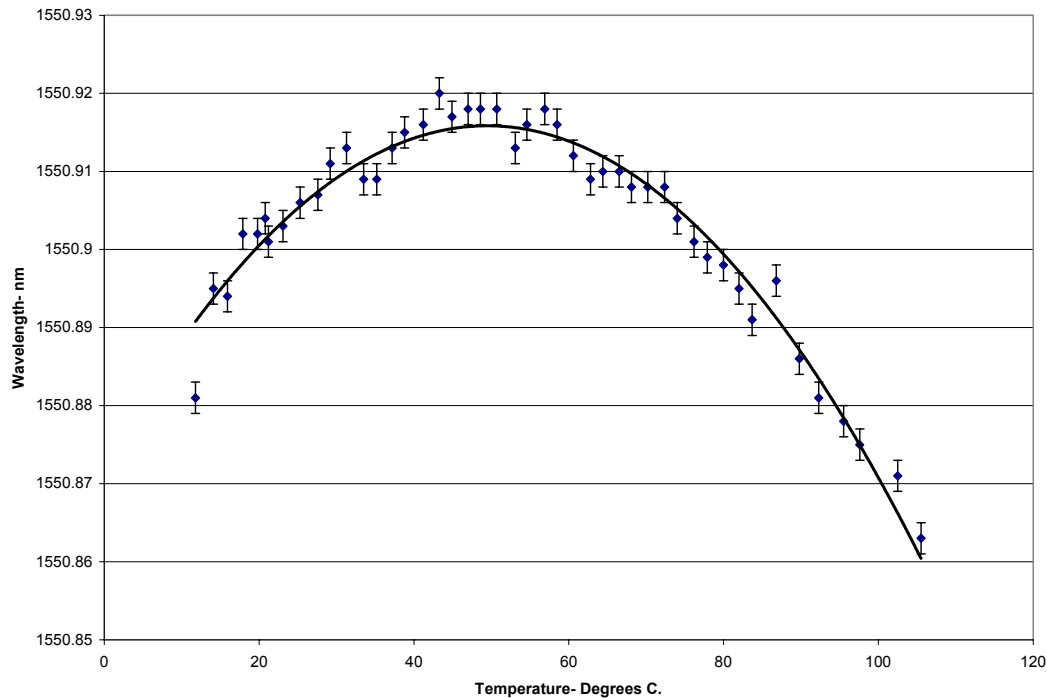


Figure 2. Wavelength drift of a single YVO₄ filtering element with a temperature-compensating crystal. A quadratic equation was used to fit the data.

In addition, we have developed temperature-compensation methods for other birefringent materials such as TeO₂. Please contact us with your specific temperature-compensation requirements, and we will work with your technical staff to develop a custom solution.

Isomet Demultiplexer: Technical Description

Since Isomet has considerable experience designing acousto-optic components that utilize birefringent materials, we decided to expand our capability by developing the mathematical tools required to design birefringent filters for telecommunications. In the case of demultiplexers/de-interleavers, for a desired passband shape we can calculate the required crystal dimensions and orientation. In addition, we have the ability to generate filter designs that are insensitive to temperature variation. The second-generation Isomet Demultiplexer is an example of our prototyping capability. The tunable, passively temperature-compensated 100 GHz device (Figure 3) measures 25 x 32 x 143 mm³.

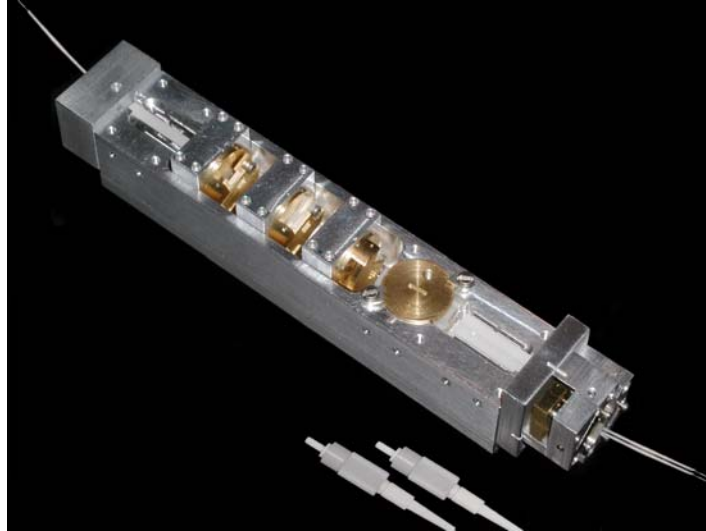


Figure 3. Second-generation Isomet Demultiplexer.

The crystal layout of the second-generation Isomet Demultiplexer is shown below in Figure 4. Elements 1, 2, 4, 6, 8, 9, 10, 11 in the Figure are all anti-reflection-coated TeO_2 crystals (other birefringent materials such as YVO_4 can also be used). The input beam enters the device from the left via the input fiber and passes through birefringent beamsplitter 1 where it is split into two orthogonally polarized beams. The beams then pass through crystal pairs 2/3, 4/5, 6/7 which act as wavelength-filtering elements (high-order waveplates) to create the desired passband. Crystal 3, 5, 7 are the temperature compensators for crystals 2, 4, 6. After passing through the filtering elements, the two beams are randomly polarized. Then the two beams enter crystal pair 8, 9 and, in turn, crystal pair 10, 11 (we term this patent-pending sub-assembly the polarization intermixer) where the horizontal and vertical components of the two beams are swapped. Additional detail on the intermixer can be found in the document entitled “Polarization Intermixer”, which is available from Isomet. The two output beams now consist of even and odd frequencies at twice the frequency spacing of the input beam. The passbands for the two output channels are shown below in Figure 5, which was generated by placing crystals 2-7 between crossed (green) and parallel (black) polarizers. This design can be easily modified to accommodate additional filtering elements, as required to create the desired passband.

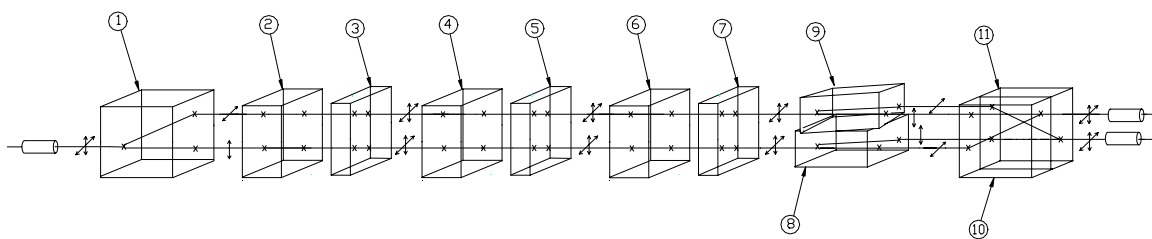


Figure 4. Schematic of the second-generation Isomet Demultiplexer.

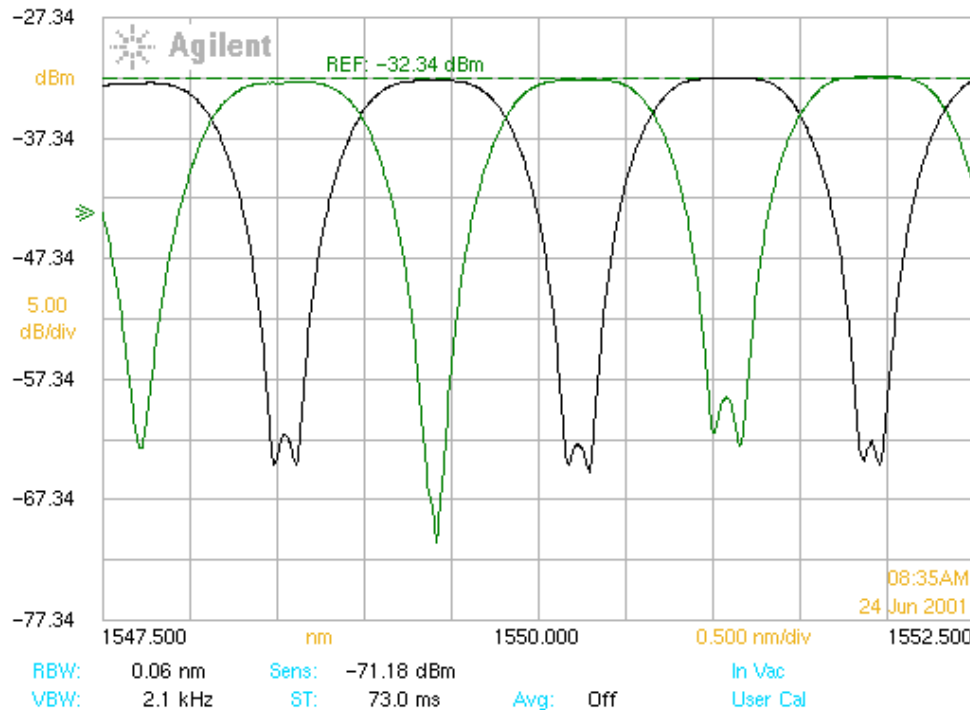


Figure 5. Odd and even channel passbands of the second-generation Isomet Demultiplexer. Crystals 2-7 were placed between crossed (green) and parallel (black) polarizers. Note that the adjacent channel rejection exceeds 25 dB.

Summary

We have demonstrated our ability to develop prototype passive components based on birefringent materials. Isomet now offers the following design and prototyping services:

- Design of temperature-compensated birefringent filters to produce a desired passband.
- Growth of both PbMoO_4 and TeO_2 with the ability to fabricate, polish, dice, and anti-reflection coat these and other birefringent materials (YVO_4 , LiNbO_3 , and TiO_2). Thus we can quickly fabricate prototype filter parts.
- In house test instrumentation (HP86142B Optical Spectrum Analyzer, Agilent 83438A Erbium ASE Source, Agilent 11896A Polarization Controller, and Agilent 81640A Tunable Laser Source) required to characterize fully the performance of prototype birefringent filters.
- Manufacture of processed birefringent crystals and assemblies in high volume.