III-6. Demodulation of Microwave Frequency-Modulated Light Using Birefringent Crystals

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At present, the most promising technique for demodulating frequency-modulated (FM) light is to convert the FM signal to an AM signal; the AM signal can then be demodulated by a microwave phototube, photodiode, or other means. This paper deals with the discrimination process, i.e., the conversion of FM light to AM light. In particular, we describe several discriminators composed of birefringent crystals and polarizers.

The first of these, conceived by Harris in 1962, is the *birefringent discriminator*. The birefringent discriminator consists of an input polarizer, a birefringent crystal, and a output polarizer, as shown in Fig. 1. Basically,

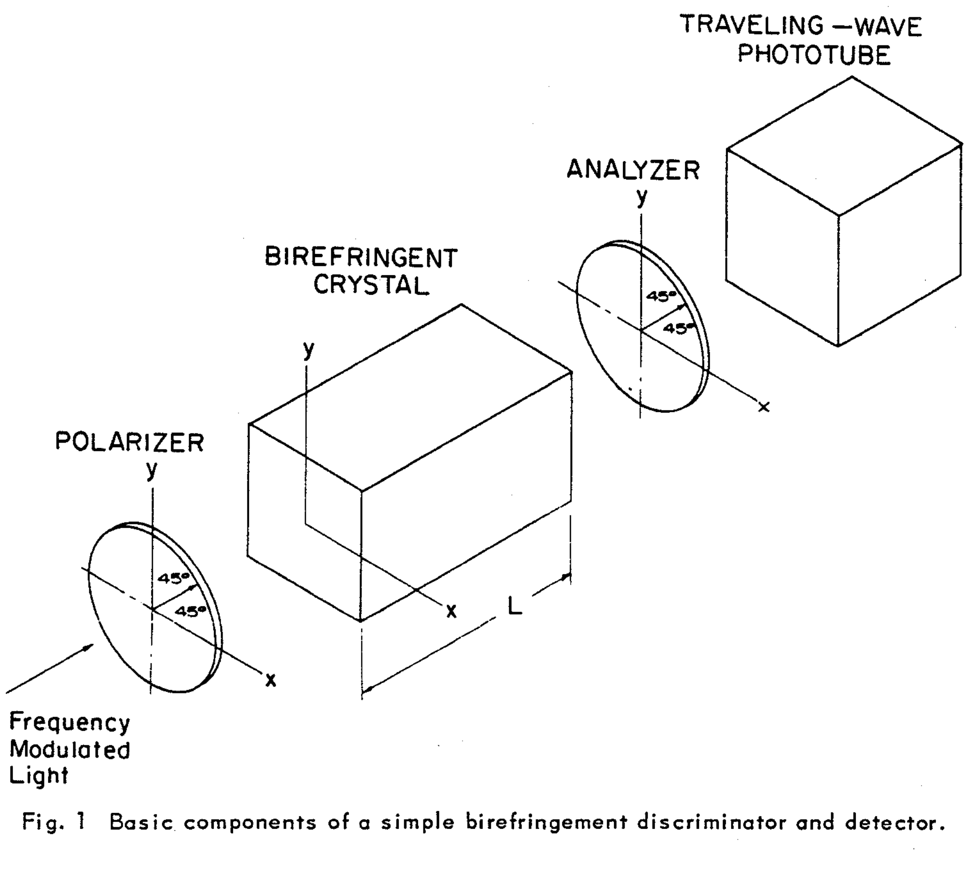

Fig. 1 Basic components of a simple birefringement discriminator and detector.

the operation of the birefringent discriminator is as follows: The optical signal, after passing through the input polarizer, has equal components along the two birefringent axes of the crystal. These two components propagate with unequal velocities through the crystal and interfere at its output. The resulting frequency transmission characteristic is shown in Fig. 2.

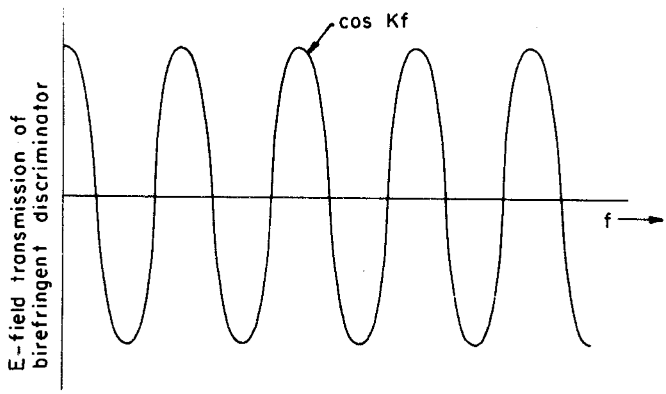

Fig. 2 Frequency characteristic of birefringement discriminator.

The birefringent discriminator can be used in several different ways, only one of which has been described previously, to convert FM to AM. The best known method is to choose the length of the crystal so the period of the frequency transmission characteristic of Fig. 2 is four times the modulating frequency, f_m. This choice of crystal length results in the maximum AM signal out for a given FM signal in. However, in this case, the discriminator operates properly only for frequencies at or near f_m.

Two new modes of operation have also been found. One of these occurs when the crystal length is shorter, causing the period of the frequency transmission characteristic to be much larger than f_m. In this case, the output AM is smaller than in the first method, but the discriminator can operate properly over a much wider frequency range. Still another new method of operation is possible, in which the input light is split into two equal portions prior to reaching the discriminator. Only one portion passes through the discriminator; at the discriminator's output, it is recombined with the first beam.

A modification of the birefringent discriminator proposed by Harris and Buhrer resulted in the device shown in Fig. 3. This device is termed the *optical ratio detector* and is obtained from the birefringent discriminator by replacing the final polarizer by a second birefringent crystal whose axes are rotated 45° from the first. The optical ratio detector offers the advantage of a larger AM output from a given FM input. In addition, the ratio detector suppresses AM signals. New experimental results are given for the FM to AM conversion properties and the AM suppression properties of the ratio detector.

The cos Kf curve of Fig. 2 is, in reality, a very simple frequency characteristic. It is apparent that the FM to AM conversion process can be improved by using a discriminator whose frequency characteristic is more

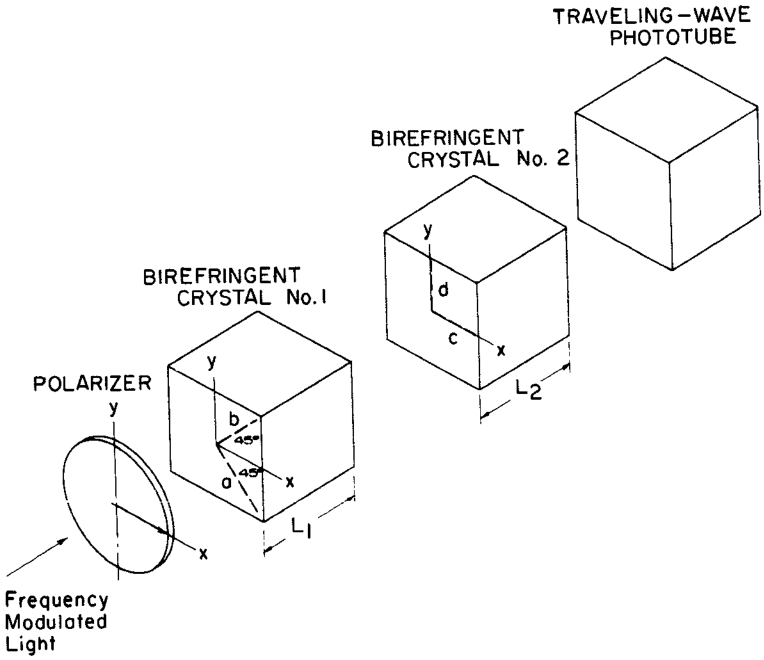

Fig. 3 Basic components of the optical ratio detector.

complicated. A technique has been found for realizing *any* desired frequency characteristic using only birefringent crystals and polarizers. The resulting "optical filter" has the following form: The filter contains n identical birefringent crystals and two polarizers—one at each end of the filter. The birefringent crystals are all the same length, but are placed so their birefringent axes lie at various angles. The synthesis technique prescribes the crystal angles necessary to obtain a desired filter characteristic.

Using this technique, an improved discriminator is designed and discussed.