Extinction ratio

1. What is the polarization of light?

Polarization refers to the phenomenon that the vibration vector of shear wave (perpendicular to the propagation direction of wave) deviates in some certain directions. The longitudinal wave is not polarized.
Light is a shear wave, that is, a wave whose vibration direction and wave forward direction are perpendicular to each other. Light whose vibration direction is limited to a certain fixed direction is called "polarized light", and its virbration direction is called "polarized direction". Like the rope being shaken in the figure below.

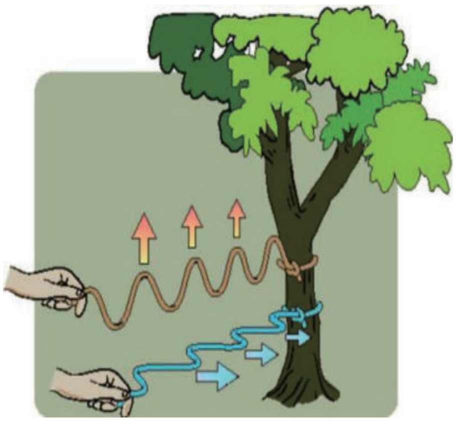

Fig. 1

The polarizer is like a gap. The gap will only allow waves shaking parallel to it to pass through. The energy of the wave shaking perpendicular to it will be absorbed by the wall of the gap because the rope hits the wall of the gap.

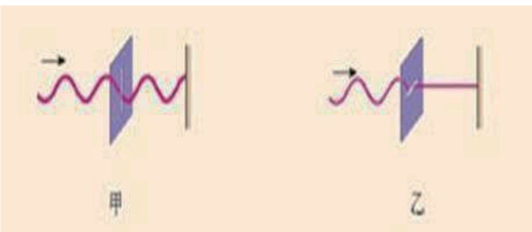

Fig.2 Polarizer

2. What is extinction ratio?

The actual polarizer device is always not ideal. What is obtained after natural light transmission is not completely linearly polarized light, but partially polarized light. Therefore, even if the light transmission axes of the two polarizers are perpendicular to each other, the transmitted light intensity is not zero. The ratio of the minimum transmitted light intensity at this time to the maximum transmitted light intensity parallel to the transmission axes of the two polarizers is called extinction ratio.

3. How should extinction ratio be expressed?

There are generally three representations.
Linearity ratio = P1 / P0
power measurement (dB) = $10\log_{10}$ (P1 / P0)
percentage% = (P0 / P1) × 100

4. What does it represent?

In the field of polarization optics, extinction ratio has significance in at least three aspects:
(1) For polarizing devices that produce linearly polarized light, such as polarization splitting prisms, the extinction ratio is defined as the ratio of the main transmittance to the main extinction transmittance, which is used to characterize the ability of polarizing devices to obtain linearly polarized light.
(2) The linearly polarized light is required to be incident perpendicular to the optical axis of the sample. Because the sample has a certain thickness, the outgoing light will produce the phase difference between ordinary light (o light) and unusual light (e light), and the polarization state will change. At this time, the extinction ratio reflects the magnitude of stress birefringence in the crystal.
(3) It is suitable for linearly polarized light incident along the optical axis of the crystal. At this time, the polarization state of the light does not change and the direction of the light vector rotates by a certain angle. Therefore, this extinction ratio can characterize the optical rotation property of the crystal.

5. Influencing factors

The influencing factors of extinction ratio can be considered from the following aspects:

(1) Temperature difference. Differences of temperature will lead to the change of circuit element parameters, affect the power, and cause the change of extinction ratio.

(2) Optical path cleanliness difference. The cleanliness of the optical path will affect the loss of optical power, but the power change values of P1/P0 are not linear (molecular denominator minus the same value), and the extinction ratio will become larger according to the definition.

(3) Polarizer. The influence of extinction ratio of analyzer on extinction ratio.

(4) Polarization state of light wave. The polarization state of light wavedirectly determines the extinction ratio.

6. Why test the extinction ratio?

Extinction ratio is one of the main optical parameters of crystal materials and polarizing devices. Its size is an important index to measure the performance of polarizing devices. The extinction ratio parameters of polarizing devices need to be known exactly after processing and before actual use. The accuracy of extinction ratio measurement will affect the detection accuracy of measuring and identifying the polarization properties of various light radiation by polarizing devices, as well as the detection and analysis of the polarization response of other optical devices and instrument systems with polarization conversion properties by polarizing devices. With the continuous development of laser polarizing technology, polarizing devices are increasingly widely used in optical fiber communication, polarizing navigation, optical modulation, photoelectric detection, optical sensing and other technical fields. Therefore, the accurate measurement of extinction ratio of polarizing devices is of great significance for the development of modern information technology.

7. In what range?

Polarization extinction ratio is the proportional relationship between two orthogonal polarization components decomposed along the main polarization state direction, and the unit is dB. 100:1 means 20dB and 10000:1 means 40dB. For the polarizer, the higher the extinction ratio, the stronger the ability to change the input light into linearly polarized light. For the light source, the higher the extinction ratio, the closer the output light will be to the linearly polarized light. Theoretically, the energy of polarized light on the line is completely concentrated in one direction, and the extinction ratio is infinite; the energy of circularly polarized light is evenly distributed in two orthogonal directions, and the extinction ratio is 0; elliptically polarized light with extinction ratio between 0 and infinity; since the energy on each axis is equal, the extinction ratio of non-polarized light is 0. In fact, the extinction ratio of 40dB is quite high, and the extinction ratio of low polarization source is generally less than 0.5dB.

Typical values vary from device to device, 18-20db in many passive devices and 50-60db or higher in some polarizers or polarized optical waveguides. PER can also be used as a depolarizer or low polarization light source for proxy measurement of degree of polarization (DOP). In this case, the PER will be close to 0 because the light is evenly distributed across all polarizations. The smaller the extinction ratio, the higher the degree of polarization of the polarized light generated by the polarizing device. The extinction ratio of the artificial polarizer is about $10 \sim 10^{-3}$.

8. Measuring method

The existing extinction ratio measurement methods include double optical path method, orthogonal polarization method, double prism method, double modulation method, high extinction ratio method and so on.

(1) Double modulation method

The extinction ratio of polarizing prism is defined as:

$$\rho = T_1 / T_2 \qquad (1)$$

In the formula (1): T_1, T_2 is the main transmittance of the polarization prism to be measured. Let I0 be the light intensity of linearly polarized light emitted from the polarizer and incident on the polarizing prism to be measured. According to Marius' law, the emitted light intensity meets:

$$I = I_0 \cos^2\alpha \quad (2)$$

In the formula (2): α Is the angle between the optical axis of the polarizing prism crystal to be measured and the optical axis of the polarizer. Let I1 be the output light intensity when α= 0°, that is, the optical axes of the two crystals are parallel, and I2 be the output light intensity when α= 90°, that is, the optical axes of the two crystals are vertical, with $I_1 >> I_2$. Because T_1=I1/I0 and T_2 = I2/I0, so the extinction ratio of polarizing prism can also be calculated by detecting the light intensity value, that is:

$$\rho = I_2 / I_1 \quad (3)$$

Formula (2) proposes that the existence of included angle error da will affect the detection of outgoing light intensity. When dα= 0.5 °, the detection error of light intensity is about 0.09I0. If the measurement accuracy of extinction ratio parameter is to reach 10-6, the light intensity value needs to be measured accurately, so the included angle error is required to be very small. In this experiment, the magneto-optical modulation method is used to realize the high-precision positioning of the angle between the crystal optical axis of the polarization prism to be measured and the optical axis of the polarizer, and then complete the accurate measurement of the extinction ratio parameters.

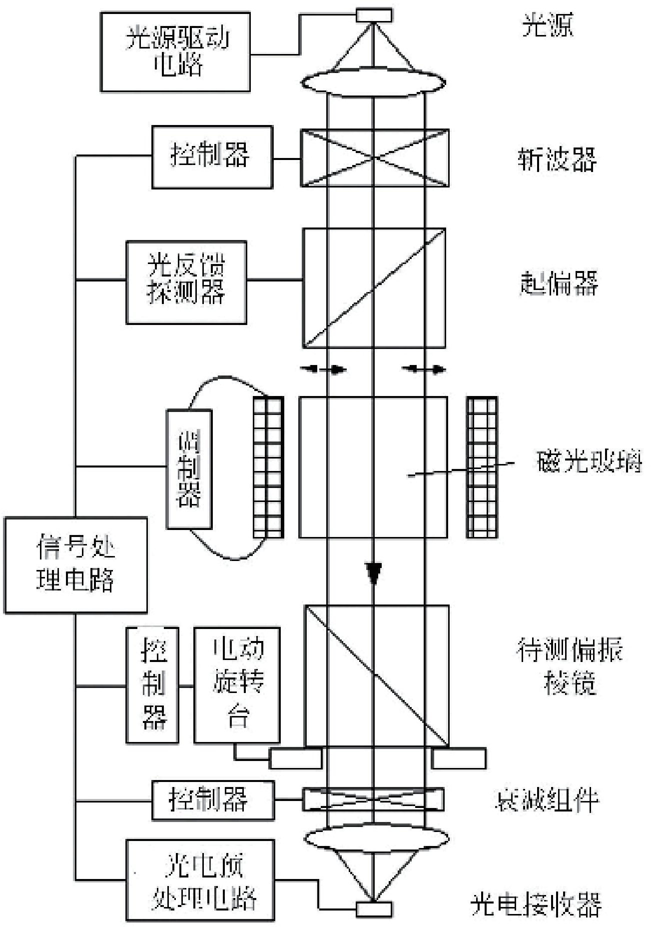

Fig. 3 Schematic diagram of double modulation method

During the experiment, put the polarization prism to be measured into the main optical path and put it on the electric rotating table, turn on the magneto-optical modulator, rotate the polarization prism to be measured to make the detector in the extinction position, and IKI ≤ K,α= 90°; Keep the position of the polarization prism to be measured unchanged, turn off the magneto-optical modulator and turn on the chopper to conduct square wave modulation on the light intensity signal, and detect the light intensity value I_2 at the extinction position. Similarly, continue to rotate the polarization prism to be measured so that K I < ≤ K0, at this time α= 0 ° (180 °), and measure the light intensity value I_1 when the optical axes of the two polarizing prism crystals are parallel, so that the extinction ratio of the polarizing prism to be measured can be obtained according to formula (3).

(2) Orthogonal polarization method

Fig. 4 is the schematic diagram of the measuring principle and device of extinction ratio. L is the 532 nm laser light source, P1 and P2 are the polarizer and analyzer, S is the sample to be measured, D is the optical power meter, which is connected with the computer for data export

In the test, firstly, rotate the sample with the light as the axis to make the crystal optical axis parallel (or perpendicular) to the vibration direction of the linearly polarized light vector; then the stepper motor drives the analyzer to rotate continuously with the light as the axis, and the computer records the minimum light intensity $I_\perp$ and maximum light intensity $I_\parallel$. Substitute the measured light intensity into the following formula to calculate the extinction ratio of the measured sample. In order to reduce the measurement error, the average value is taken as the extinction ratio test result of the sample.

$$\rho = 10 \lg(I_\parallel / I_\perp)$$

In the national standard GB/T 11297.12-2012 "measurement method of extinction ratio of optical crystals", a beam of light with a wavelength of 632.8nm passes through a tested crystal placed in an orthogonal polarizing system along the optical axis of the tested crystal, rotates the crystal with the optical axis as the axis, measures the maximum transmitted light intensity, and then rotates the analyzer into a parallel polarizing system to measure the transmitted light intensity, and calculates the extinction ratio (EX) through the formula $EX = I_{\parallel} / I_{\perp}$.

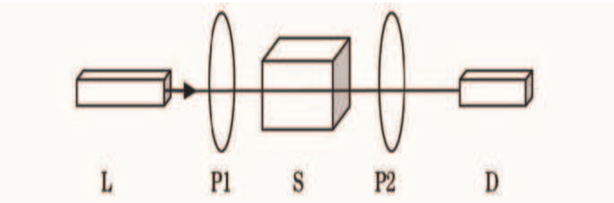

Fig. 4 Schematic diagram of extinction ratio measuring device

（**3**）Double prism method

Only two prisms to be measured and a general collimation detection system are needed. The advantage is that the polarization parameters of two prisms to be measured can be measured at the same time without standard polarizing devices. The measurement results are not affected by the partial polarization effect of the light source and the polarization response of the detector, and the polarization parameters of the instrument can be measured at the same time. It is suitable for continuous spectrum measurement on spectrophotometer, monochromator and other instruments, and is easy to realize automatic data processing. The disadvantage is that there are many parameters to be measured in the experiment, and the measured parameters are easy to be affected by the outside world, the measurement accuracy is difficult to improve, and the calculation is quite complex and cumbersome. The measurement principle is relatively simple and the actual operation is cumbersome.

（4）High extinction ratio method

In order to eliminate the polarization of the light source, two high-quality polarizing prisms with parallel main sections are combined.

It is a standard polarizer to improve the polarizing effect. The fluctuation of the light source is controlled by the servo power supply. For the problem of inaccurate manual adjustment of the measured data at the minimum point, the method of continuous rotation and synchronous recording is adopted, that is, the driving system drives the polarizer to rotate continuously, the recorder synchronously records the variation curve of the transmitted light intensity, and processes the data according to the recording results, so as to obtain the extinction ratio of the polarizer to be measured.

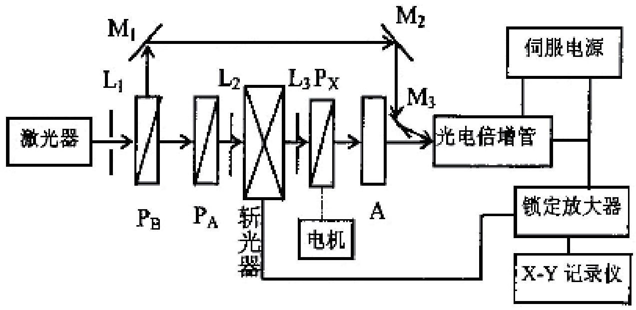

Fig. 5 Schematic diagram of high extinction ratio test

9. Error sources in experiments

Instability of light source, extinction ratio of polarizer and nonuniformity of sample absorption.

The system is complex, needs to use attenuators or frequently adjusts the optical path, which introduces more errors.

Nonlinear fluctuation of transmitted light intensity caused by non-vertical incidence of light.

Measurement error caused by extinction position positioning error.

10. Matters needing attention

The measuring system shall be in an environment without vibration and air flow.

The measurement system shall adopt light shielding measures.

When the measured crystal is placed on the V-shaped groove, any factors causing stress on the crystal shall be avoided.

Before measurement, make the measured crystal the same as the ambient temperature.

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