# An Optical Characteristic Testing System for the Infrared Fiber in a Transmission Bandwidth 9-11μm

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## ABTRACT

The high-performance measuring device is an essential tool to test the transmission characteristics of fibers since the most significant optical parameter for the infrared fiber is the transmission loss of the optical energy. The optical characteristic testing system proposed in this letter includes two parts: ① a tunable $CO_2$ laser system with a good stability and high resolution. A special design for the laser configuration leads to its good mechanic and thermal stability. In order to improve the spectral resolution, a theoretical method of the spectral resolution is proposed through the theoretical and experimental research. Besides, we make a precise design for the wavelength tuning outfit that is controlled by a computer so that a tunable laser with 99 spectral lines in the bandwidth 9-11μm is obtained. ② the testing system for the transmission loss of fibers. The optical parameters of the infrared fibers are processed and analyzed by a computer and the final testing results are output from a printer.

**Keywords:** infrared optical fiber, testing system, $CO_2$ laser

## 1. INTRODUCTION

The infrared fiber generally refers to a type of optical fibers in a transmission bandwidth 2-25μm and is used for the energy and information transmission and signal sensing in the infrared bandwidth. Especially for the infrared fiber in which the $CO_2$ laser (9-11μm) can be transmitted, its special application advantage on the infrared radiation makes the research in this field become a recent study hot spot. The current fibers for the $CO_2$ laser energy transmission are made of the chalcogenide glass, the thallium halides, the silver halides polycrystal and the antimony halide glass that is studied by my center recently. The antimony halide glass fiber has been acknowledged as the most promising $CO_2$ laser light-guide fiber internationally. In the transmission bandwidth of 8-12μm, the 10dB/km transmission loss and the transmission power near a hundred watts will be achieved in next few years. The application prospect of this fiber to the medicine, military and fine processing is very attractive.

The most important optical parameter of the infrared fiber is transmission loss. For the energy transmission infrared fiber in particular, the transmission loss represents its practical application prospect. Therefore, the R&D department for the infrared fiber should equip the optical characteristic testing system to seek the high quality fiber materials and improve the technological level through the constant monitoring and analysis. Hence testing device is definitely a necessary tool for the infrared fiber fabrication.

This letter proposes an optical characteristic testing system we made for the infrared fiber and corresponding measuring method. The whole system composes of two parts: one is a tunable $CO_2$ laser with a high stability and resolution. The laser adopts a special configuration and the rang for branch-selecting is 9.134-11.016μm containing 99 independent spectral lines. The line resolution is up to $0.96cm^{-1}$; single line output power is over 5W; long-term power stability is up to ±1.5%; single line operation drift is less than 3% and no spot drift occurs. The other is a fiber testing equipment, including the splitter, the He-Ne laser coaxial direction, the laser focalizer, the fiber coupling binder, the fiber platform, the power sensor and the analyzing, recording and processing devices for the testing results, etc. The whole equipment is connected and controlled by a computer.

## 2. THE TUNABLE $CO_2$ LASER SYSTEM

In order to achieve the precise measurement to the fiber transmission loss, one of keys is to set up a tunable

$CO_2$ laser with a good performance. The performance requirements include: (1) The output power stability should be as good as to ensure that the laser power drift does not occur in the testing process and the testing accuracy is improved then. (2) The quite stable diffusion of laser and the spot size in the testing process guarantee that the spot drift does not occur and then the "laser-fiber" coupling resolution and stability are improved as well. (3) The line resolution is good enough to achieve the continuous line scanning branch-selecting operation and the pure single line operation. In the single line operation, the laser has a high purity and a good wavelength stability. In the scanning tuning operation, the relative position and power of each line require a considerable stability and a high repeatability.

Based on the above requirements, the laser system we studied and fabricated employs the following special approaches.

① The configuration of the laser cavity.

We use the completely external cavity shown as Figure 1 in order to guarantee the high power and beam stability. The laser discharge tube *b*, the total-reflection mirror $M_1$ and the grating-rotating table are all fixed on a granite substrate 3cm thick so that a solid cavity brace isolation area is attained. Due to the small thermal expansion coefficient of the granite material, this type of cavity configuration has a quite good thermal stability and anti-mechanical shakiness stability so as to reduce the power and beam drift in the working process dramatically.

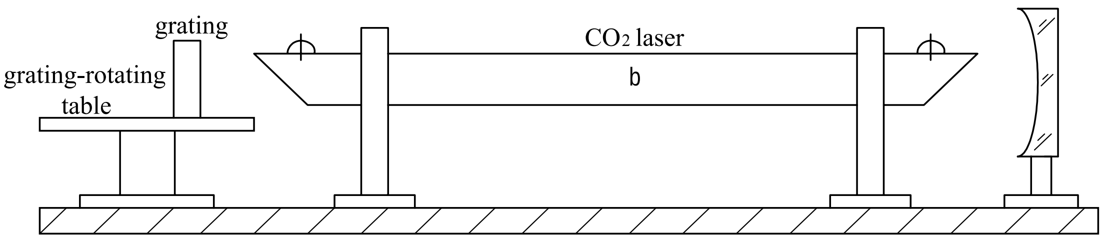


Fig.1 the cavity configuration of the $CO_2$ laser with a completely external cavity

Shown as Figure 1, the laser resonator is a grating cavity including the total-reflection mirror $M_1$ and the grating *G*. The grating in the cavity functions as a feedback mirror and a branch-selecting component as well. In order to achieve the laser pure single line operation, the grating cavity is required to have a good spectral line resolution. So we propose a formula as following to present the grating cavity resolution after careful theoretical and practical study.

$$\Delta\lambda = 2d(\frac{a + w_s}{R})\cos\alpha \quad (1)$$

In the above equation, *d* is the grating constant; $\alpha$ is the grating blaze angle; *a* is the diameter of the discharge tube; *R* is the radius of the total-reflection mirror. The study shows that it is benefit to improve the spectral line resolution of the grating cavity by using the total-reflection mirror with a large radius. Through increasing the radius of the total-reflection mirror, the laser has a very good branch-selecting resolution.

② The configuration of the tuning (branch-selecting) device.

To increase the laser output power, we use a special grating cavity that the first-order diffraction of the grating is the cavity feedback oscillation and the zero-order diffraction is the laser output coupling form. In the whole branch-selecting process, the output laser beam moves widely twice as the amplitude of the branch-selecting tuning angle. The device thus employs the "combined coupling" output configuration as Figure 2. That is to fix the planar mirror $M_2$ and the grating *G* together on the grating-rotating table and their intersection of the reflective planes is the rotation axis. The rotating table is drove by a reversible electric motor (or a stepper motor or a servo motor) so as to ensure both the direction of output beam and the position of which each line focalizes on the head face of the coupling fiber invariable in the branch-selecting process of a bandwidth 9-11μm. The grating tuning azimuth angle and the position of the corresponding output line are determined with a good repeatability. The laser is able to work not only as a continuous branch-selecting operation, but also a fixed single line operation. In the single line operation, the phenomena of the wavelength drift or the "jumper" never occur. The stabilized voltage and current supply system guarantee the stable working state of the laser.

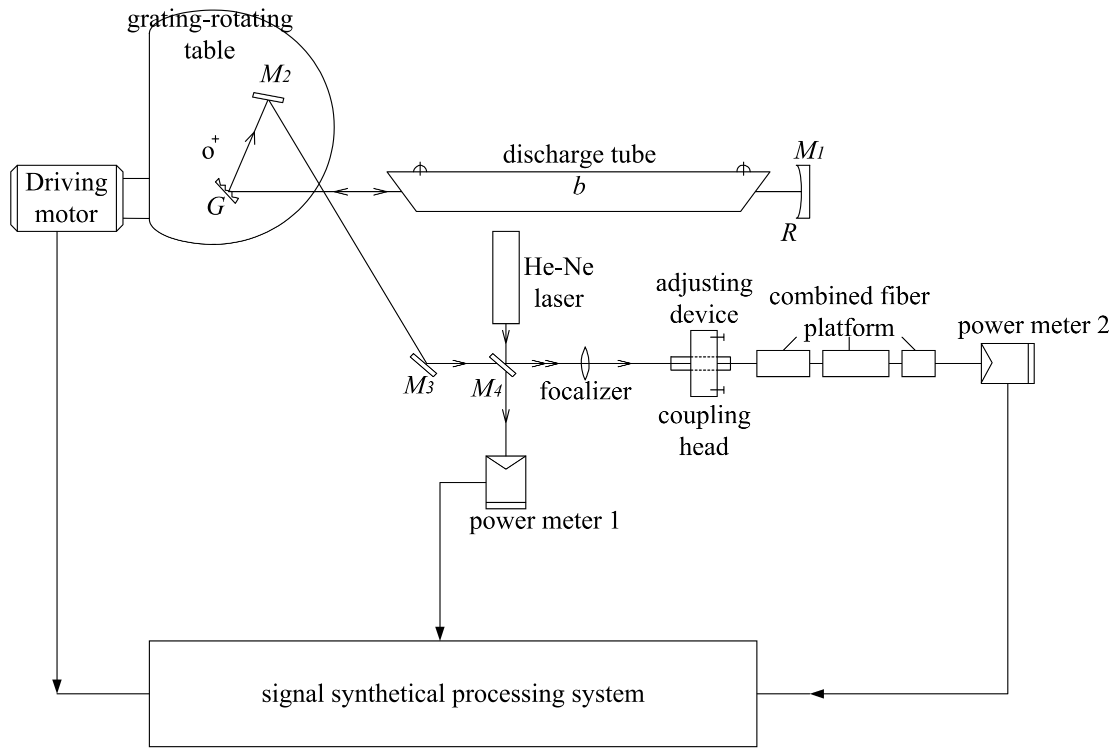


Fig.2 testing system for the transmission characteristics of the infrared fiber

## 3. THE INFRARED FIBER TESTING SYSTEM AND THE TESTING METHODS

### 3.1 Laser-fiber coupling device

The output laser is reflected by planar mirror $M_3$ and then reaches the beam-splitter $M_4$. $M_4$ is a ZnSe planar slice and placed with 45° to the light path. At first, we test the beam-splitting ratio of the beam-splitter in a bandwidth 9-11μm and record the results in the computer. The laser reflected by the beam-splitter is received by the power meter 1 as the reference signal to the laser incident to the head face of the fiber and the laser drift signal. The laser through the beam-splitter is focalized by a focalizer (It is generally a lens made of ZnSe material.) and the focal point collimates the head face of the measured fiber. As the visible coaxial direction, simultaneously, He-Ne laser is reflected by the 45° beam-splitter and then focalized on the head face of the fiber through the focalizer. One point that should be mentioned is to adjust their relative phase carefully so as to keep them confocal.

### 3.2 The adjustment device for the coupling chuck and the fiber platform

We design lots of the coupling chucks with various radiuses to cater to the different infrared fibers. The coupling chuck is equipped the 5-D adjusting bracket and can realize many fine tunings, like up, down, left, right, forwards, backwards, pitch, etc. so as to make the head face of the fiber collimate to the laser focal point. The fibers behind the coupling chuck are placed on the fiber-combined platform with some grooves and we can change their relative positions freely to suit the fibers with different lengths. The testing device composes of the reflector $M_3$, the beam-splitter $M_4$, the focalizer $f$, the coupling chuck and the fiber platform etc. that are all fixed on am optical guide track. There places a power meter 2 at the end of fiber to test the transmissive power.

### 3.3 The test for the fiber transmission loss and the result processing

The signal from the power 1 and 2 and driving motor controller are input into the "the signal synthetical processor" to analyze, process and record the testing results. The signal synthetical processor composes of the computer, A/D converter and recorder etc.. The computing equation for the fiber transmission loss is following.

$$\alpha = \frac{1}{l} \ln \frac{P_{out}}{P_{in}} \qquad \text{(dB)} \tag{2}$$

In the above equation, $l$ is the length of the measured fiber; $P_{out}$ is the transmissive power of the fiber and $P_{in}$ is the power incident onto the head face of the fiber. For the $P_{in}$, we must note that its actual value is the result that the total power incident to the head face of the fiber subtracts the part of power reflected by the head face. The reflection index is determined by the refractive index of the fiber material, the optical state of the head face and the incident direction. All these parameters are determined by the calculation and test for the various sample materials and then recorded in the computer as the invariable original parameters.

In the practical measurement, the complicated optical states on the head face of the fiber often influence the testing resolution. Therefore, people usually use the "interception method" to test a fiber. That is to finish a test and cut off a length of fiber and then test the same fiber. The transmission loss is represented as the following equation (3).

$$\alpha = \frac{1}{(l_1 - l_2)} \ln \frac{P_{out-2}}{P_{in-1}} \qquad \text{(dB)} \tag{3}$$

In the above equation, $l_1$ is the length of the original fiber; $l_2$ is the length of the residual fiber; $P_{out-1}$ is the transmissive power in state of $l_1$; $P_{out-2}$ is the transmissive power in state of $l_2$; This testing and calculating method avoids the influence of the reflective state of the fiber head face.

The processing and calculation for the measured parameters are completed by the computer. The possible power fluctuation in the testing process is monitored by the power meter 1 and regarded as the background data through the A/D converter to be normalized in the computer processing. The final value of the fiber transmissive loss is printed on a record sheet directly.

If using the stepper motor or the servo motor to drive the grating-rotating table, we can utilize $CO_2$ laser spectral line analyser to scale the output lines and the corresponding tuning angle in advance so as to obtain the azimuth angle signal of each line as a sort of the original parameters kept in the computer also. In the later testing process, therefore, we only need to drive the motor controller to input the corresponding tuning signal into the signal synthetical processor. Finally the corresponding line serial number and wavelength are printed from the printer automatically.

## 3. CONCLUSION

The testing system for the transmission characteristics of the infrared fiber this letter proposed is applicable to various fibers in the bandwidth 9-11μm. The whole device has plenty of favorable advantages, such as the good resolution and stability, the convenience and the high automation level. We surly believe that this device will display all kinds of advantages and turn to be a reliable tool for the measurement of this field through our further optimization.

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