

TECH INFO

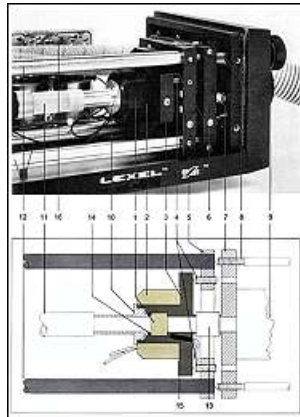
FEATURES OF LEXEL LASERS: SINGLE-FREQUENCY OPERATION

The Lexel Model 503 Temperature-Controlled Etalon Assembly, when installed in a Lexel ion laser, provides extremely stable single frequency operation for applications requiring long coherence length and very narrow linewidth. For holography and interferometry, it can provide coherence lengths of over 100 meters. For Brillouin scattering and high resolution spectroscopy, it provides a linewidth of approximately 10^{-4} cm^{-1} (3 MHz).

To view a close-up picture and diagram showing the Model 503 installed in a laser, click the photo at right.

The etalon assembly

The Lexel Model 503 Etalon Assembly utilizes a solid fused-silica etalon in a precisely temperature-controlled oven to provide the ultimate in frequency stability and controlled mode tuning. The temperature stabilization circuit maintains the etalon frequency within ± 20 MHz regardless of the change in ambient temperature, thus assuring virtually no mode hopping. The temperature tuning feature allows the selection of any single longitudinal resonant mode within the Doppler-broadened gain bandwidth without the need to readjust the etalon tilt angle.



The etalon therefore **operates at its maximum conversion efficiency**, and the laser user may easily select the single mode that yields maximum power. The potentiometer controlling the etalon temperature is adjustable without removing the laser cover. A flashing LED indicates that the electronic temperature regulating circuit is operating properly.

The etalon heater is hermetically isolated from the optical cavity -- thus completely eliminating the possibility of the heater contaminating the etalon surfaces or other optical components.

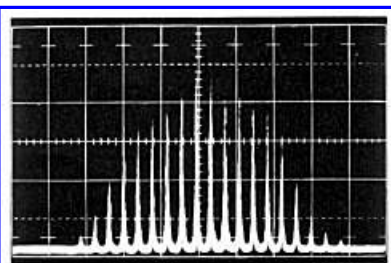
The Model 503 Etalon Assembly is kinematically mounted on the laser Invar[®] resonator structure using the same stable suspension system as is used on the Lexel mirror mounts. This effectively integrates the etalon assembly with the total optical resonator structure for maximum mechanical and thermal stability.

Single frequency using the tilted etalon

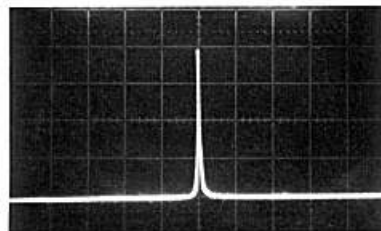
The tilted etalon has long been recognized as a simple but effective method for producing single frequency output from ion lasers. An etalon, when placed in the laser cavity and tilted slightly, acts as a bandpass transmission filter. The etalon will pass frequencies close to its transmission peak and reject, by reflection, frequencies outside the etalon passband. The normal frequency spectrum of an ion laser is made up of 20 to 40 individual longitudinal modes covering a bandwidth of approximately 5 GHz. The longitudinal mode spacing ($c/2L$) is 188 MHz in the case of a laser with a 0.8 meter mirror spacing, and 150 MHz with a 1 meter cavity.

The installation of the etalon will force the laser into the single longitudinal mode closest to the center of the etalon's passband.

Etalon tuning and conversion efficiency



Multiple frequency: Normal longitudinal mode spectrum of a typical argon ion laser using a scanning Fabry-Perot interferometer.



Single-frequency: Spectrum analyzer display of single longitudinal mode output

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Single-frequency: Spectrum analyzer display of single longitudinal mode output from a Lexel ion laser with the Model 503 Etalon Assembly.

Maximum single frequency power is obtained only when the peak of the etalon passband coincides with the longitudinal mode at the center of the laser gain bandwidth. Therefore, the etalon must be frequency-tuned to achieve the optimum single frequency performance. In order to tune an etalon it is necessary to vary its effective length either by increasing the etalon tilt angle or by changing the index of refraction. An air-spaced etalon has a fixed optical length and index of refraction and can be tuned only by increasing the tilt angle. Such angular tuning, however, is accompanied by an increasing walk-off loss which can seriously limit the single frequency power.

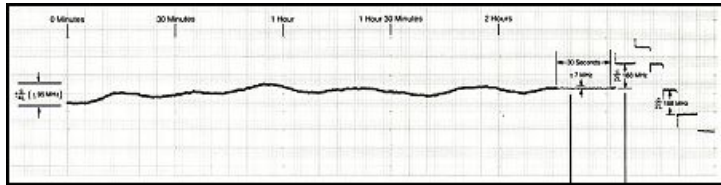
Fortunately, the solid fused-silica etalon is easily tuned by making use of the change in index of refraction with temperature (dn/dT). The same temperature-controlled heater system that is used to stabilize the etalon can be used for the temperature tuning. The etalon passband peak will change approximately 4 GHz/°C (or 40 MHz/.01 °C).

The Lexel Model 503 Etalon Assembly **can be precisely tuned over the full 5 GHz laser bandwidth**, and the longitudinal mode having the maximum power easily selected. The etalon tilt angle, which is preset for maximum efficiency, does not have to be changed. Conversion efficiencies (single longitudinal mode power) / (multilongitudinal mode power) of more than 75% can be achieved with Lexel argon lasers in the strong 488.0 nm and 514.5 nm lines.

Solid fused silica versus air-spaced etalons

The original solid fused-silica etalons were used without temperature stabilization. This resulted in considerable mode hopping and frequency drift. The air-spaced etalon consisting of two thin windows bonded to a hollow, thermally stable spacer was developed to overcome this difficulty. Although the air-spaced etalon produced good thermal stability, the walk-off loss that accompanies the required angular tuning and the additional reflection losses caused by the two extra optical surfaces often result in reduced laser power.

The Lexel Model 503 Etalon Assembly is unquestionably the most superior etalon system available today. Its advanced



temperature control circuit stabilizes the efficient solid fused-silica etalon to a degree unequaled by any other type of etalon and, at the same time, provides the flexibility of convenient temperature mode tuning.

Click on the photo above to see an enlarged view of a typical strip chart test record, showing the frequency stability that can be achieved with the Model 503.

Operation of the Model 503 Etalon Assembly

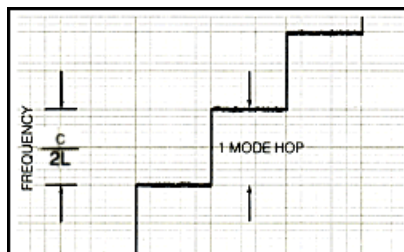
The operation and tuning of the etalon is extremely simple. The tilt angle of the etalon is set at the factory for maximum efficiency. Although this adjustment is easily accessible at the back of the laser head, it should never have to be readjusted even after tuning to another laser wavelength.

All etalon tuning is accomplished by adjusting the Etalon Temperature Tuning control at the side of the laser head. Successive longitudinal modes can be selected by turning this control approximately $\frac{1}{4}$ turn for each mode. The effect of the tuning on the single frequency performance can be easily monitored using a scanning spectrum analyzer and a laser power meter such as the Lexel Model 504. The Oven Indicator is a flashing red LED which shows the status of the electronic temperature regulating circuit.

Mode hopping and frequency stability

The frequency stability of a mechanically stable, single-frequency laser depends primarily on the temperature stability of (1) the etalon length and (2) the laser cavity length. Each of these two parameters, if allowed to vary with changes in ambient temperature, produces a different effect on the laser frequency stability.

(1) **Etalon length changes.** If the etalon is not temperature stabilized, the effective length of the etalon and the resulting etalon transmission frequency will drift with the ambient temperature. When the etalon passband moves to the point where it interacts with the next longitudinal mode, the laser frequency will jump to

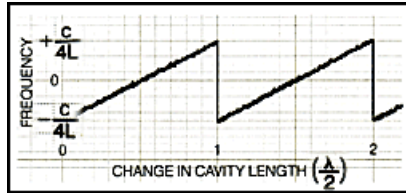


this new mode. This is the well-known "mode hopping" phenomenon. Mode hopping causes stepwise changes in the laser frequency which can result in frequency excursions of several thousand MHz.



Since the Lexel Model 503 Etalon Assembly is temperature stabilized to within 0.01 °C (±20 MHz) regardless of ambient temperature changes, **there is virtually no mode hopping.**

(2) **Cavity length changes.** Thermal expansion of the optical resonator will change the cavity length. This results in the laser frequency varying along the etalon transmission curve. When a new mode enters the curve, the initial mode disappears, and the frequency excursion starts back at its initial point. Cavity lengthening causes a sawtooth change in laser frequency with a maximum frequency excursion of $\pm(c/4L)$; for example, ±95 MHz for a 0.8 meter cavity, ±75 MHz for a 1 meter cavity.



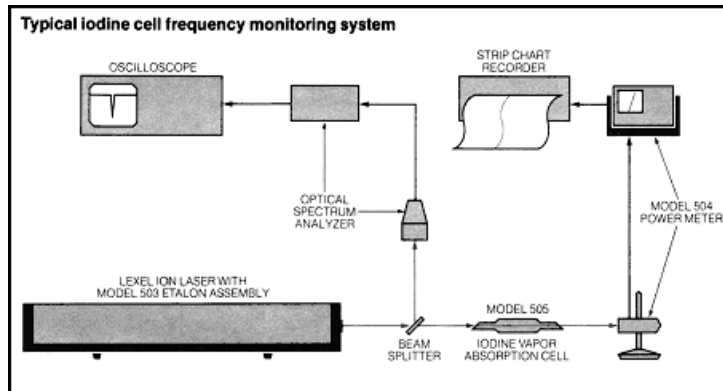
The total frequency stability of a single-frequency ion laser depends on a number of characteristics of both the laser's physical construction and the operating environment. The major variables are the resonator's coefficient of thermal expansion, the ambient temperature variation, and the time period involved.

The standard Lexel Invar Resonator has a thermal expansion of less than $0.9 \times 10^{-6}/^{\circ}\text{C}$ with a resulting frequency stability of better than 0.5 GHz/°C. This is **over 25 times better than the best aluminum resonator.** The optional 7510 Thermally Compensated Resonator Length reduces the effective expansion to less than $10^{-7}/^{\circ}\text{C}$ with a frequency stability of better than 50 MHz/°C for the most stringent long-term performance.

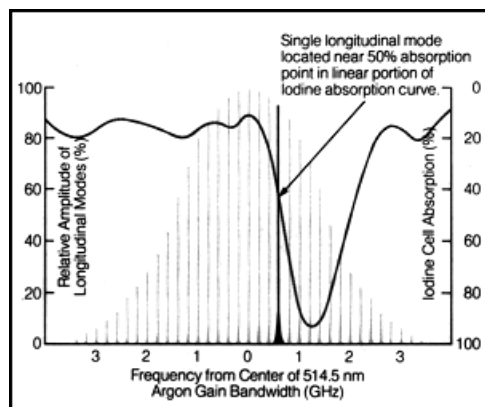
With either resonator Lexel single frequency lasers are capable of frequency stability better than ±75 MHz for periods of up to 10 hours when operated in a good laboratory environment. Short-term frequency stability of better than ±5 MHz has been achieved.

Iodine cell frequency monitoring

The frequency stability of a single frequency ion laser is best measured by using an iodine absorption cell. The absorption curve of iodine vapor is shown below in relation to the frequency bandwidth of the 514.5 nm argon laser line.



On the sharp linear portion of the absorption curve very small changes in frequency result in large changes of power absorption. If a constant amplitude output from the single frequency laser is passed through the iodine cell into a power meter, the changes in measured power provide a direct and accurate indication of the frequency shift. An iodine cell frequency monitoring system allows the long-term frequency stability to be recorded very accurately. Frequency variations of less than ± 5 MHz can be resolved with such a system.



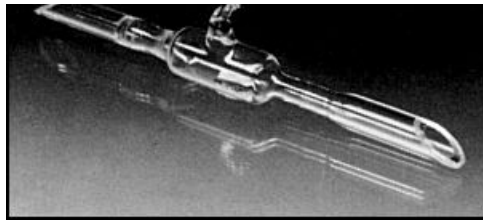
Every Lexel argon laser that is equipped with a Model 503 Etalon Assembly is checked for frequency stability using the iodine absorption cell technique. A ten-hour strip chart record, is made on each unit prior to its shipment.

Lexel Model 505 Iodine Cell

We have available a very convenient iodine



vapor absorption cell for use in measuring the frequency stability of single-frequency argon lasers. The Lexel Model 505 Iodine Cell has a 150 mm absorption path through the sealed, vacuum-processed, cell chamber. The ends of the iodine cell are terminated with high quality Brewster's angle windows which match the polarized laser output for minimum reflection losses.



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