SR-003 TECHNICAL APPLICATION NOTE

Broadband and Multiline Source Analysis with SuperCavity™

Introduction

SuperCavity is a non-confocal, spherically symmetric Fabry-Perot Interferometer manufactured by Newport Corporation. This compact interferometer has exceptional efficiency and extremely high finesse, which allows it to be used for detailed investigations and analysis of coherent and quasi-coherent mode structures in a near-real time environment. On occasion, however, it may also be desirable to use a Fabry-Perot interferometer, such as the Newport SuperCavity, to analyze the spectrum of either broadband or multi-line sources. This Newport Technical Application Note addresses such an analysis.

Broadband and Multiline Case Analysis

The free spectral range (FSR) of a Fabry-Perot interferometer is c/2L, where c is the speed of light, and L is the optical path length between the two mirrors. In SuperCavity, the optical path length and, therefore, the FSR is a function of the total voltage swing applied to the piezo-ceramic cylinder separating and holding the interferometer's two mirrors. This FSR corresponds to the interferometer cavity mode resonances, i.e. it is the distance between overlapping modes. If a gain medium is present in the cavity between the two mirrors, then coherent amplification may occur at these cavity resonances, and under certain conditions, the interferometer becomes a laser. The FSR is then referred to as the longitudinal mode spacing of the laser modes.

SuperCavity FSR's are nominally 6 GHz for SR-100 series, and 8000 GHz for SR-200 series. For spectral analysis of broadband sources, such as laser diodes and bright incoherent sources, the large FSR of the SR-200 series SuperCavity may be preferrable because it can provide an unambiguous and non-overlapping scan of the source's frequencies. On the other hand, the high resolving power of the SR-100 series SuperCavity with its 6 GHz FSR may be preferable in other applications.

To assist in the selection of the appropriate SuperCavity for a specific application, three common broadband sources are examined using both a FSR of 6 GHz and 8000 GHz. It will be assumed in the first two applications that the source mode structure is narrower than the Fabry-Perot transmission window. The third application will address sources whose output is wider than the transmission profile of the interferometer All the applications assume that the detector used has a flat frequency response.

1. Two-Mode Laser

In this first application, the SuperCavity interferometer is used to analyze a laser having two modes separated by 7.5 GHz, as shown in Fig. 1. The output of the interferomter is found by using the process of convolution of the interferometer's resonances with the laser's spectrum. This is done by scanning, i.e. moving horizontally, Fig. 1(b) against Fig. 1(a) and integrating the product of the two waveforms. The scanning parameter in this analysis is the voltage applied to the piezoelectric ceramic cylinder. A voltage increase produces a slight decrease in the optical path length between the two mirrors, resulting in a shift of the interferometer's resonances towards the high end of the frequency spectrum, as is indicated in Fig. 1(b).

The output signal of the Fabry-Perot interferometer (Figure 1(c)) represents the frequency spectrum of the laser as it is usually displayed on an oscilloscope. As already noted, this output is basically the convolution of the laser's 7.5 GHz mode spacing with the 6 GHz cavity resonances of the interferometer (such as the SR-100 Series SuperCavities). To a casual observer, Fig. 1(c) implies that the laser's two modes are separated by either 1.5 or 6 GHz, when, in reality, the separation is 7.5 GHz. Such confusion is enhanced if many lasing modes are present or if the linewidth of the broadened laser line is more than the FSR of the interferometer (as in Application #3 below). If the same laser mode structure is convoluted with the resonances of an interferometer having a FSR of 8000 GHz, such as is shown in Fig. 1(d), then the convolution presented in Fig. 1(e) shows that the previous confusion is eliminated. Of course, if the laser mode structure spacing is much less than the FSR of the interferometer (i.e., less than 6 GHz in this case) no ambiguity will result.

2. Multiline Laser Emission

A second common application involves multiline lasers such as chemical lasers, some of which are known to emit coherent light at several transition lines simultaneously. Each emission line may have its own longitudinal and transverse mode structure. Figure 2(a) shows a laser operating on two lines indicated by v_1 and v_2. For convenience, these two lines are referred to as red and blue, respectively.

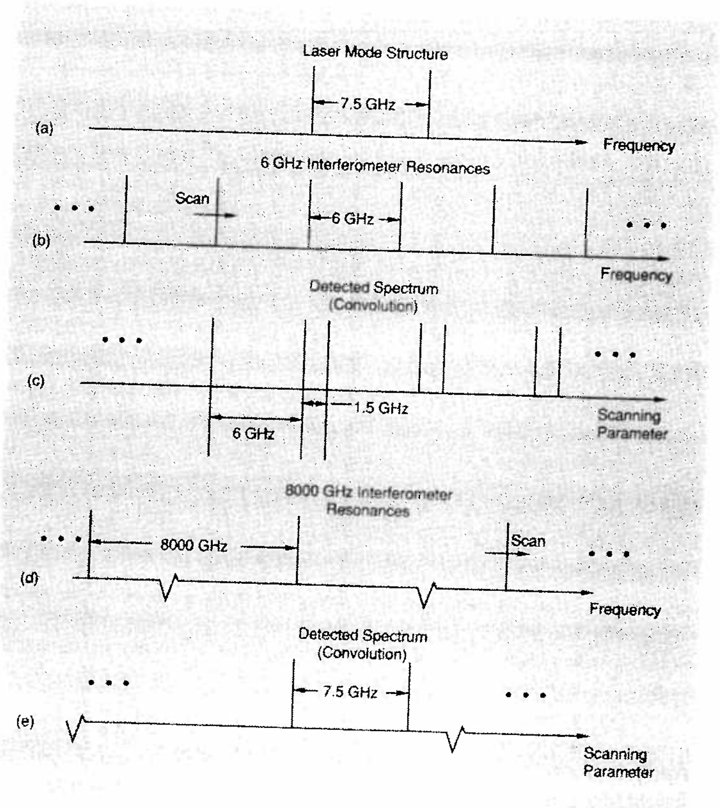

Fig. 1. The output of a Fabry-Perot interferometer used to examine the spectrum of a laser with two longitudinal modes. (a) The spectrum of the laser's output is composed of two modes separated by 7.5 GHz. (b) The resonances of the interferometer showing a FSR of 6 GHz. (c) The interferometer's output as the convolution of (a) with (b). This convolution is the detected intensity as (b) is scanned versus (a). The scanning parameter is the voltage applied to the piezo transducer. Note the overlap between the modes in (c). (d) The resonances of the interferometer showing a FSR of 8000 GHz. (e) The convolution of (a) with (d). Note now the lack of overlap between modes in (e).

The red line is shown operating with two longitudinal modes, while the blue line is operating with one. The number of lasing modes and their detunings from line center for each line is a function of the relative position of the laser's resonances with respect to the gain profile of the amplifier. To clarify the identity of individual longitudinal modes, each one is given a different amplitude. This amplitude is naturally a function of the gain-to-loss ratio for that laser mode. The laser cavity resonances are indicated by a series of vertical dashed lines in Fig. 2(a). The resonances of the Fabry-Perot interferometer with a 6 GHz FSR is shown in Fig. 2(b).

As explained in Fig. 1, the detected spectrum revealed by the Fabry-Perot is the convolution of Fig. 2(a) with 2(b), with the co-incident resonances shown in Fig. 2(c). Note the interlacing of the modes from the two lines for each scan width, and again the ambiguous output. This situation can become even more complicated in the case of broadband molecular transitions. If an interferometer with an 8000 GHz FSR is used (Fig. 2(d)), the resulting spectrum (Fig. 2(e)) is unambiguous.

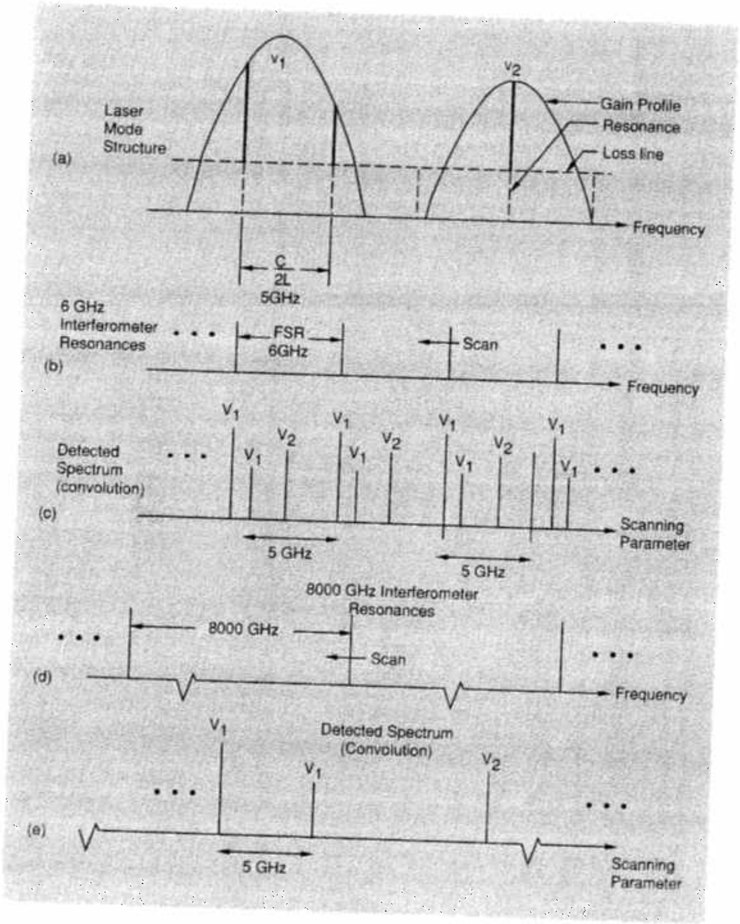

Fig. 2. The output of a Fabry-Perot interferometer used to examine the spectrum of a laser operating with two lines: v_1 having two longitudinal modes and v_2 having one longitudinal mode. (a) The frequency spectrum of a laser showing loss line, gain profile and cavity resonances. The amplitudes of the active modes are shown with bold lines. (b) The resonances of a 6 GHz interferometer. (c) The convolution of (a) with (b). Note the interlacing of the modes in each order and the ambiguous results. (d) The resonances of an 8000 GHz interferometer. (e) The convolution of (a) with (d), producing an unambiguous output spectrum.

3. Continuous Broadband Source

The source examined in this third application has a continuous and broad spectrum with a linewidth that is broader than the FSR of the Fabry-Perot (see Fig. 3(a)). Examples of such spectra are found in the fluorescence emission spectra of dyes, Nd-Glass, and laser diodes.

The Fabry-Perot interferometer has as before a transmission profile corresponding to its resonances. It acts as a sampling window, transmitting only those frequencies that happen to be present within the range of its transmission window. The output therefore is the sum of the transmitted intensities. Scanning the interferometer results in the convolution of Fig. 3(a) with 3(b) and is shown in Fig. 3(c).

The different transmitted frequency components that pass through the transmission window of the interferometer are incoherent with each other. Figure (3c) represent the portion of Figure (3a) that falls under Figure (3b) as (3b) is scanned. Hence, the resultant intensity distribution shown in Figure (3c) is the incoherent sum of the intensities of the individual components. Also, the transmitted intensity may represent only a tiny fraction of the overall laser's output, i.e. the interferometer's detected output intensity in Figure (3c) is very small as compared to the initial intensity of the source.

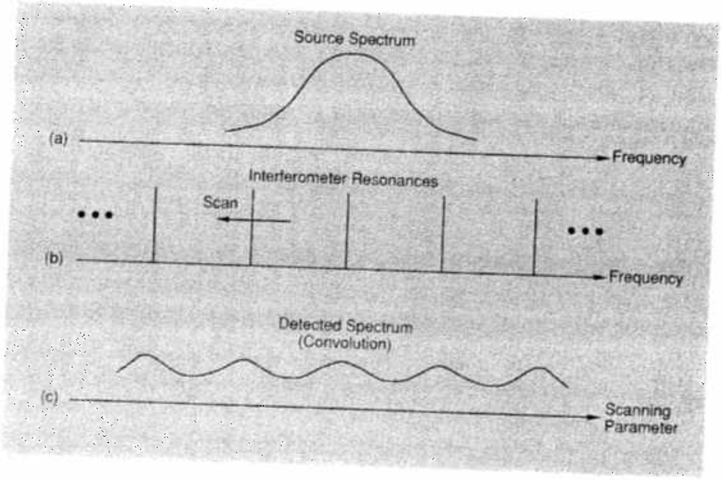

Fig. 3. The output of an interferometer used to examine a broad emission spectrum. (a) The spectrum of the source. (b) The interferometer's cavity resonances. (c) The interferometer's output, the convolution of (a) with (b).

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