Chirped Fiber Bragg Grating

Good morning, everyone, my name is Zhang Hao, now, I’ll start my presentation about “Chirped Fiber Bragg Grating”.

As we know, when a fundamental mode propagates in a single mode fiber with a long distance, especially in a high-bit-rate communication system, the biggest limitation is pulse broadening due to dispersion, which makes it difficult to filter out certain wavelength.

Of course, this also leads to another question: what if we want to compensate the dispersion of SMF?

When we embed a grating with non-uniform periods in the fiber, we can get the chirp. This grating is called a Chirped Fiber Bragg grating (CFBG). Every section of CFBG can be treated as Bragg grating. As we know, when light waves propagate in a medium, they always observed energy conservation and momentum conservation, the vectors of incident wave, grating, and reflected wave satisfy this equation, finally we can get Bragg condition. So, if optical wavelength equals Bragg wavelength, it will reflect out from input port.

Ok, there is a pulse with some different wavelength of ,,, when we launch the pulse into the short-period section of CFBG, optical signals with different frequencies are reflected back at different positions of the CFBG, we can see that short-wavelength light is reflected by the grating first, while long-wavelength light is reflected on the far right of the grating. In other words, the speed of blue-shift component is quick, and the speed of red-shift component is low, they have different velocity, which will cause different time delay, so, the output pulse is broadened.

And if we launched the broadened pulse formed by this situation from the large period of the CFBG, we can see that the red-shift component will be reflected back first when it reaches Bragg condition, and the blue-shift component will be reflected at the right side of the CFBG, therefore, we can recompress or restore the broadened pulse.

Using the CFBG, we can also achieve the optical delay line, as shown in Figure 4. The first CFBG will disperses the pulse, and the pulse will be compressed through the second CFBG. When one of the gratings is stretched, the physical delay between the two gratings is altered and a time delay is introduced.

If you want know more about CFBG, please refer to these two textbooks.

// 结束 以下是中文版

With above analysis, we can see that the Bragg condition varies as a function of position along the grating. This is achieved by ensuring that the periodicity, Λ, or the mode effective index *neff*, varies as a function of position. We can also get the Chirped Bandwidth, the figure 4 shows the reflectivity of a step chirped grating.

在具有光放大、长距离、高比特传输率的通信系统中，数字传送的一个最大局限性就是色散导致的脉冲展宽。

由于光纤光栅器件具有体积小、插入损耗小、与光纤的兼容性较好、受非线性效应影响小、易于集成、色散补偿率高以及波长选择性好等众多优点，近年来，光纤光栅已成为光纤通信领域中较为成熟的色散补偿技术之一，大色散的特点使得啁啾光纤光栅能很好的补偿光脉冲在传输过程中引入的色散。

根据光线折射率变化周期是否恒定，我们将光纤布拉格光栅分为均匀光纤布拉格光栅（UFBG）与啁啾光纤布拉格光栅（CFBG）两种。由于CFBG的反射谱范围较大，不同频率的光信号在光纤光栅的不同位置满足布拉格条件被反射回来，由此产生的传输时延恰好补偿了在普通单模光纤传输中的群速度时延，CFBG多作为色散补偿器。而UFBG的反射谱范围较小，多作为光滤波器，用来反射单一频率的光信号。

光脉冲在反常色散介质普通单模光纤中传输时，蓝移分量传播速度快，因此脉冲的前沿部分频率高，红移分量传播速度较慢，使得脉冲的后沿部分频率低。若使光纤光栅周期大的一端在前，周期小的一端在后，使得脉冲的红移分量在光栅的前端达到布拉格条件被反射回来，蓝移分量在光栅的后端才被反射，从而重新压缩甚至还原展宽的脉冲。光栅对蓝移分量和红移分量所产生的最大时延差的计算公式为：



其中，*Vg*为光脉冲在光纤光栅中的传播速度，*Lg*为光纤光栅的长度。在光栅中，蓝移分量比红移分量多传输了2*Lg*的距离，上式即为高频分量和低频分量的最大时延差。

Research On Dispersion Compensation Technology Using Fiber Bragg Grating

基于光纤布拉格光栅的色散补偿技术研究 刘雯 浙江工业大学硕士学位论文

布拉格光栅条件实际上是满足动量与能量守恒的另一种简单表达形式而已。能量守恒(hwf=hwi)要求入射光与反射光频率相同。动量守恒则要求入射波矢量Ki与光栅波矢量K之和等于反射波矢量Kf，这个关系可以简单表示为



光栅的波矢量K幅度大小为2π/A，方向与光栅面的法向一直。反射波矢量与入射波矢量的大小相等，方向相反。因此，动量守恒条件变为



可以简化为





式中，光纤布拉格光栅波长是光纤布拉格光栅反射回来的入射光在自由空间中的中心波长；neff是光纤纤芯针对自由空间中心波长的折射率。

啁啾光纤布拉格光栅可以被看做是沿光纤轴向改变光栅的周期A或者纤芯的折射率系数，或者两者都改变。从上市可以得到



啁啾光栅最简单的结构形式是光栅周期的变化呈线性：



The refractive index profile of the grating can be modified to add other features, such as a linear, quadratic, or jump variation in the grating period. Therefore, the gratings have a non-uniform period along their length; this form is called a chirp, as shown in Figure 1.5. In a chirped FBG, the Bragg condition varies as a function of position along the grating. This is achieved by ensuring that the periodicity, Λ, varies as a function of position, or that the effective mode index, neff, varies as a function of position along the FBG, or through a combination of both. In this case, the reflected wavelength changes with the grating period, which results in a broadening in the reflected spectrum. A grating possessing a chirp has the property of adding dispersion, in which different wavelengths reflected from the grating will be subject to different delays [2, 3].

Chirped gratings have many important applications. Particularly, linearly chirped grating has found a special place in optics, such as a dispersion-correcting and compensating device [32, 33]. This application has also triggered the fabrication of ultra-long, broad-bandwidth gratings of high quality, for high-bit-rate transmission [34] and in WDM transmission [35]. Some of the other applications include chirped pulse amplification [23], chirp compensation of gain-switched semiconductor lasers [27], sensing [26–29], higher-order fiber dispersion compensation [35], amplifier gain flattening [3], and band-pass filters [2]

Othonos, A., and Kalli, K. Fiber Bragg Gratings-Fundamentals and Applications in Telecommunications and Sensing, Artech House, Boston, MA, 1999.

Kashyap, R. Fiber Bragg Gratings, Academic Press, 2009.

we note that the chirp in the period can be related to the chirped bandwidth, Dlchirp of the fiber grating as