# Transmission Function of Cascaded Multilayer Medium Thin Film Filter

Chen Haiyan[1)2)] Liu Yongzhi[2)] Dai Jizhi[2)] Zhang Xiaoxia[2)]

1) Dept. of Physics, Yangtze University, Hubei JingZhou 434023, P.R. China

Tel: 86-716-8430182, Email: uestcchy0470@sina.com.cn,

2)School of Optoelectronic Information, University of Electronic Science and Technology of China, Chengdu , 610054,P.R.China,

**Abstract:** A cascaded multilayer medium thin film filter used for flattening the gain of erbium-ytterbium co-doped waveguide amplifier(EYCDWA) is presented. The transmission function of cascaded multilayer medium thin film filter is obtained.

**Keywords:** Integrated optics device; optical amplifiers; optical waveguide amplifier; folded erbium-ytterbium co-doped phosphate glass waveguide; cascaded multilayer medium thin film filter; gain flattened

## 1 Introduction

Recently, monolithic integration of optical amplifiers and pumping lasers, and filters is very attractive because of their high stability, low size and cost, potential application in optical communication system and optical signal processing[1]. The rapid growth of the internet and data traffic in optical fiber communication networks has stimulated the study of high gain and wideband waveguide amplifiers[2][3]. In our previous works we proposed several broad bandwidth waveguide amplifier structures for higher total gain and flattened gain bandwidth[4][5].

The transmittance performance of the multilayer medium thin film filter(MMTFF) is described approximately by the *n*th Butterworth's function[6], when the intrinsical gain jitter of erbium-doped waveguide amplifier is small, it acts very well, otherwise, its effect is small. In this paper, we propose a cascaded multilayer medium thin film filter (CMMTFF) to flatten the gain of erbium-ytterbium co-doped waveguide amplifier with arbitrary gain jitter, it consists of some different MMTFF unit cell with different central wavelength and bandwidth, and each of which can suppress a certain gain peak at a specific wavelength. As an example, a S-type wideband erbium-ytterbium co-doped phosphate glass waveguide amplifier(EYCDWA) integrated with cascaded multilayer medium thin film filter is presented, and the transmission function of which is obtained.

## 2 Model

Fig.1 shows the configuration of S-type EYCDWA integrated with CMMTFF. Signal light from a laser diode at 1.55μm wavelength region mixed with pump from a laser diode at 0.98μm goes through S-type geometry erbium-ytterbium co-doped phosphate glass waveguide, at the end of this S-type optical waveguide a CMMTFF at 1.55μm operation is used to suppress the gain jitter. The advantage of this configuration is that this S-type geometry waveguide path can achieve higher total gain in smaller volume, CMMTFF improves the

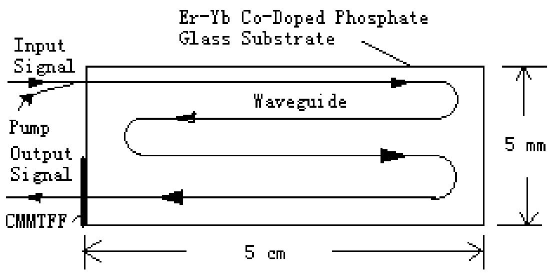


Fig.1 Configuration of S- type EYCDWA integrated with CMMTFF

flattening gain bandwidth.

The filtering characteristics of the MMTFF is described approximately by the nth order Butterworth's function[6] :

$$Trans(\lambda, \lambda_0) = a/(1+[(\lambda - \lambda_0)/\lambda_c]^{2n}) \quad (1)$$

where Trans(λ,$\lambda_0$) is the transmittance spectrum of the MMTFF, *a* is insert loss, $\lambda_0$ is the central wavelength and $\lambda_c$ half gain flattening bandwidth.

The transmittance function T of CMMTFF is

$$T = \sum_{i=1}^{N} Trans(\lambda, \lambda_i, \lambda_{ci}, n_i) = \sum_{i=1}^{N} a/(1+[(\lambda - \lambda_i)/\lambda_{ci}]^{2n_i}) \quad (2)$$

where *T* is the transmittance function of CMMTFF, and Trans(λ,$\lambda_i$,$\lambda_{ci}$,$n_i$) is the transmittance function of the *i*th MMTFF unit cell with central wavelength $\lambda_i$, half gain flattening bandwidth $\lambda_{ci}$, and $n_i$th order of Butterworth's function, respectively.

The gain of this EYCDWA through the CMMTFF at wavelength λ is

$$G(\lambda) = Gain(\lambda) + T(\lambda) \quad (3)$$

where G(λ),Gain(λ),*T* (λ) is the flattening gain spectrum, intrinsical gain spectrum(without filter) and transmittance function of CMMTFF at wavelength λ, respectively.

Based on the study of the intrinsical gain spectrum of a certain EYCDWA, using fitting method we can obtain the transmittance function of CMMTFF.

**3 Results and Discussion**

Under certain condition that the concentrations of Er and Yb are $1.51\times10^{26}$ /m$^3$ and $1.95\times10^{27}$/m$^3$, the lengths of substrate and waveguide are5.5cm and 14cm, respectively, pump power is 150mW at 980nm operation, the intrinsical gain spectrum of this EYCDWA is shown in figure 2. The jitter at the region of 1528nm ~ 1570nm is much large, besides the stronger gain peak, there are some other lower gain peak. We can choose special filtering unit cell with different central wavelength and bandwidth to suppress these gain peak.

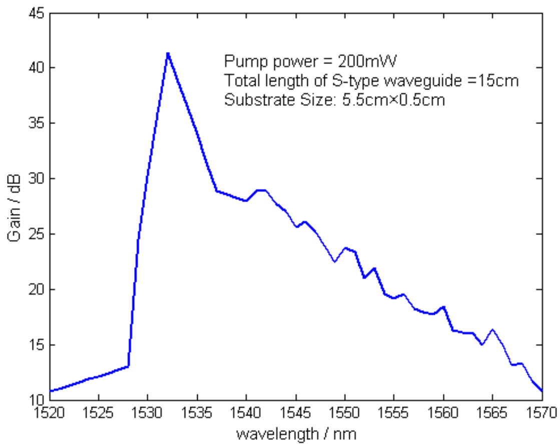


Fig.2 Intrinsical gain spectrum of EYCDWA

Fig.3 shows the effect of transmittance function of the MMTFF on output gain characteristics of the proposed EYCDWA. In Fig.3 (a), only MMTFF unit cell with a central wavelength of 1550nm, bandwidth of 30nm, and 5th order Butterworth's function, the transmittance spectrum of this MMTFF is Trans(λ,1550)=0.9/(1+[( λ-1550)/15]$^{10}$). the strongest gain peak at about 1532nm is suppressed effectively, the average gain between 1535nm and 1565nm is about 20dB with gain difference of about 8dB, it is shown that it is difficult to obtain gain flattened at a large region using only MMTFF unit cell. In order to obtain larger flattening gain bandwidth, we can use CMMTFF as shown in Fig.3(b), in which the CMMTFF consists of two unit cells, one unit cell with a central wavelength of 1550nm, bandwidth of 30nm, and 6th order Butterworth's function, the other with a central wavelength of 1550nm, bandwidth of 30nm, and 2th order Butterworth's function,, its transmittance function is $T(\lambda)=0.9/(1+[(\lambda-1550)/15]^{12})+0.9/(1+[(\lambda-1550)/15]^{4})$, it is shown that average gain of about 17dB is obtained between 1530nm and 1560nm with gain difference of below 3dB. It is possible to obtain broader bandwidth with gain difference of below 1dB by special CMMTFF.

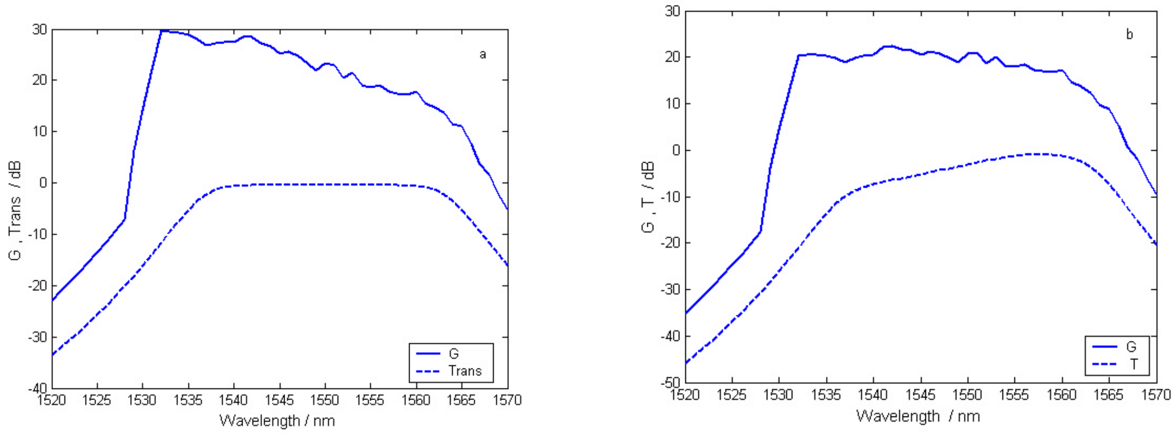


Fig.3 G,T Vs Wavelength (different filtering unit cell)

## 4 Conclusions

A cascaded medium thin film filter used for flattening the gain of S-type erbium-ytterbium co-doped waveguide amplifier is presented. Average gain of about 17dB is obtained between 1530nm and 1560nm with gain difference of below 3dB, and the transmission function of cascaded multilayer medium thin film filter is obtained. This method can deal with the EYCDWA with arbitrary profile of intrinsical gain.


## Acknowledgment

This work was supported by the National Nature Science Fund of China under granted No:90201011.


## Reference


[1] D.Barbier,"The present and future of EDWA technology," Technical program committee OFC'2002, Anaheim California,TuB3.

[2] J.M.P.Delavaux, C.Mcintosh, J.Shmulovich, A.J.Bruce, R.K. Patnaik,and B.R. Wirstiuk, "Gain flatness of a planar optical waveguide amplifier,"OFC'2000,Maryland,WA2.

[3] K.C. Reichmann, P.P. Iannone, M. Birk, N.J. Frigo, D. Barbier, C. Cassagnettes, T. Garret, A. Verlucco, S. Perrier, and J. Philipsen, " A eight-wavelength 160-km transparent metro WDM ring network featuring cascaded erbium-doped waveguide amplifiers," IEEE Photon. Technol. Lett., 13, 1130-1132(2001).

[4] Chen Haiyan, Liu Yongzhi, Dai Jizhi ,etal. "Wideband Erbium-Ytterbium Co-Doped Phosphate Glass Waveguide Amplifier". The 8th optoelectronics and communications conference(OECC'2003),2003,Oct13~16, shanghai, P.R.China,515-516

[5] Chen Haiyan, Dai Jizhi, Zeng Xuefei, Huang Xiujiang. "Design of Structure for Broad-Band Integrated Optical Waveguide amplifiers". Journal of UEST of China, 32, 264-266(in Chinese) (2003)

[6] Jin Yaohui and Zeng Qinji, "The ASE Noise Accumulation in a WDM All Optical Network" Acta Optica Sinica, 20, 195-200, (in Chinese) (2000)