



**UNIVERSITI PUTRA MALAYSIA**

**NEW TUNABLE ALL-FIBER OPTICAL COMB FILTER  
BASED ON MACHZEHNDER INTERFEROMETER**

**MD. SHAFIQL ISLAM**

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**NEW TUNABLE ALL-FIBER OPTICAL COMB FILTER BASED ON MACH-ZEHNDER INTERFEROMETER**

By

**MD. SHAFIQL ISLAM**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in  
Fulfillment of the Requirements for the Degree of Doctor of Philosophy**

**May 2011**

## DEDICATION

This work is dedicated to the loving memory of my late Grand father and father. May Allah grant them Al-Jannat Firdaus, Amin.



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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**Chair: Professor Mohd Adzir bin Mahdi, PhD**

**Faculty: Engineering**

This dissertation presents theoretical model and experimental construction and development of two tunable all-fiber comb filters based on Mach-Zehnder interferometer (MZI). The unique demonstration of this dissertation is the spectral spacing tunability and peak wavelength position shifting within the free spectral range (FSR) of the output transmission spectrum. There are two designs of MZI-based comb filter studied in the dissertation. Firstly, a tunable all-fiber comb filter based on dual-pass MZI is demonstrated in which one segment of polarization maintaining fiber (PMF) and one polarization controller (PC) are inserted in the second loop of conventional MZI. The PMF segment consists of lengths  $L_1=6$  m and  $L_2=3$  m are spliced at  $90^\circ$  about their principle axes to each other. Half wave plate (HWP) of PC is used for changing the effective length of the PMF segment from its maximum  $|L_1+L_2|$  to minimum  $|L_1-L_2|$ . The separation between two peaks, namely as spectral spacing can be adjusted to any desired

value in between 0.72 nm to 2.00 nm using the HWP. Shifting of peak wavelength position within the FSR is demonstrated using a quarter wave plate (QWP) of PC. Extinction ratios are observed in between 16 dB to 18 dB through out the experiment. The proposed dual-pass MZI-based comb filter still uses two fiber couplers which makes the design vulnerable to environmental perturbations. In order to rectify this problem, single-core fiber MZI-based tunable comb filter is demonstrated. One PMF segment consists of lengths  $L_1=7.80$  m and  $L_2=4.60$  m are spliced between two single mode fibers (SMFs) at  $45^\circ$  and  $0^\circ$  respectively. One PC is inserted in this alignment. The Spectral spacing can be adjusted to any desired value in between 0.55 nm to 1.95 nm using HWP. The peak wavelength position can also be shifted over the entire FSR with extinction ratios in between 18 dB to 20 dB.

For both comb filters, the tunability of spectral spacing and peak wavelength can be achieved by tuning the HWP and QWP of PC respectively. In addition to this, the spectral spacing can also be tuned by changing the surrounding temperature without adjusting the HWP. On the other hand, the peak wavelength shift can also be obtained by applying stress on the PMF segment without rotating the QWP. Therefore, these comb filters can be utilized as a temperature or strain sensor. Besides these potential applications, these comb filters have been tested in fiber lasers to generate multiple lasing channels simultaneously. At room temperature, more than 30 channels within 3 dB peak power variation are recorded from an Erbium-doped fiber laser incorporating the proposed comb filters.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**TURAS SISIR BARU SEMUA-GENTIAN OPTIK BOLEH TALA  
BERDASARKAN KEPADA METER GANGGUAN MACH-ZEHNDER**

Oleh

**MD. SHAFIQL ISLAM**

Mei 2011

**Pengerusi: Profesor Mohd Adzir bin Mahdi, PhD**

**Fakulti: Kejuruteraan**

Disertasi ini membentangkan model-model teori dan pembinaan eksperimen dua penapis sesikat gentian-sepenuhnya boleh tala berdasarkan kepada meter gangguan Mach-Zehnder (MZI). Keunikan demonstrasi disertasi ini ialah kebolehtalaan jarak spektrumnya dan pemindahan kedudukan panjang gelombang puncak spektrum penghantaran kelurannya di dalam julat spektrum bebas (FSR). Terdapat dua susunan penapis sesikat berdasarkan MZI telah dikaji di dalam disertasi ini. Pertama sekali, satu penapis sesikat gentian-sepenuhnya boleh tala berdasarkan MZI dwi-laluan telah ditunjukkan di mana satu bahagian daripada gentian memelihara pengutuban (PMF) dan satu pengawal pengutuban (PC) telah dimasukkan ke dalam gelung kedua MZI konvensional. Bahagian PMF terdiri daripada panjang  $L_1=6$  m dan  $L_2=3$  m yang disambat pada  $90^\circ$  berhampiran paksi-paksi utama antara satu sama lain. PC piring separuh gelombang (HWP) digunakan untuk mengubah panjang berkesan bahagian PMF

daripada maksima ( $L_1+L_2$ ) kepada minima ( $L_1-L_2$ ). Pengasingan di antara dua puncak yang dinamakan jarak spektrum boleh diubah kepada mana-mana nilai yang dikehendaki di antara 0.72 nm hingga 2.00 nm menggunakan HWP. Pemindahan kedudukan panjang gelombang puncak di dalam FSR ditunjukkan menggunakan PC piring suku gelombang (QWP). Nisbah-nisbah termusnah telah diperhatikan di antara 16 dB sehingga 18 dB sepanjang eksperimen. Penapis sesikat dwi-laluan berdasarkan MZI yang dicadangkan masih menggunakan dua pengganding gentian yang menjadikan susunan ini mudah diserang oleh gangguan persekitaran. Untuk memperbaiki masalah ini, penapis sesikat boleh tala berdasarkan MZI gentian teras tunggal ditunjukkan. Satu bahagian PMF yang terdiri daripada panjang  $L_1=7.80$  m dan  $L_2=4.60$  m disambat diantara dua gentian mod-tunggal pada  $45^\circ$  dan  $0^\circ$  masing-masing. Satu PC dimasukkan ke dalam penjajaran ini. Jarak spektrum boleh diubah ke mana-mana nilai yang dikehendaki di antara 0.55 nm sehingga 1.95 nm menggunakan HWP. Kedudukan panjang gelombang puncak juga boleh dipindahkan ke seluruh FSR dengan nisbah-nisbah termusnah di antara 18 dB sehingga 20 dB.

Untuk kedua-dua penapis sesikat, kebolehtalaan jarak spektrum dan panjang gelombang puncak dapat dicapai dengan menalakan PC HWP dan QWP masing-masing. Tambahan lagi, jarak spektrum juga boleh ditala dengan mengubah suhu persekitaran tanpa mengubah HWP. Sebaliknya, pemindahan panjang gelombang puncak juga boleh didapati dengan mengerahkan tegangan ke atas bahagian PMF tanpa memutarakan QWP. Oleh itu, penapis-penapis sesikat ini boleh digunakan sebagai pengesan suhu atau tegangan. Selain penggunaan-penggunaan yang berpotensi ini, penapis-penapis ini telah diuji di dalam laser gentian untuk menghasilkan laser berbilang saluran secara serentak.

Pada suhu bilik, lebih daripada 30 saluran di dalam variasi 3 dB kuasa puncak dicatatkan daripada laser gentian Erbium-terdop yang menggabungkan penapis sesikat yang dicadangkan.





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I certify that an Examination Committee has met on 13<sup>th</sup> May 2011 to conduct the final examination of Md. **Shafiqul Islam** on his Doctor of Philosophy thesis entitled “**New Tunable All-Fiber Optical Comb Filter Based on Mach-Zehnder Interferometer**” in accordance with the Universities and University Colleges Act 1971 and the constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15<sup>th</sup> March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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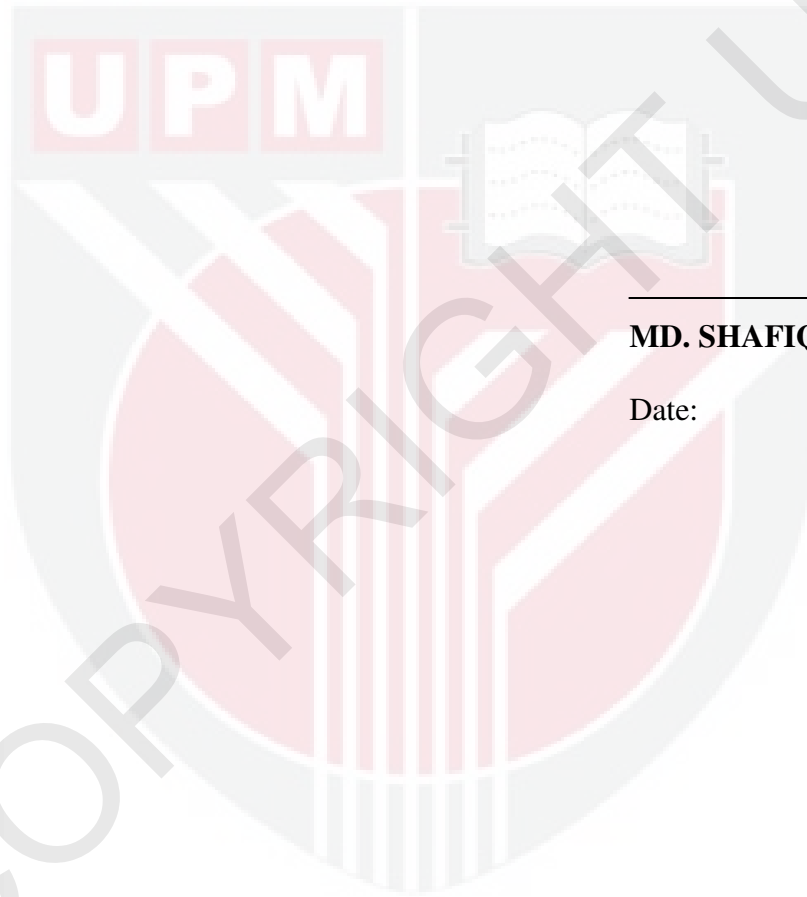
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## DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.



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**MD. SHAFIQL ISLAM**

Date:

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