行政院國家科學委員會補助專題研究計畫成果報告

通信用超快光偵測器

計畫類別：■個別型計畫　□整合型計畫

計畫編號：NSC88－2218－E－002－038

NSC89－2215－E－002－004

~~NSC89－2214－E－002－064~~

執行期間：87年8月1日至90年10月31日

計畫主持人：孫啟光

共同主持人：(無)

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□赴國外出差或研習心得報告一份

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□出席國際學術會議心得報告及發表之論文各一份

□國際合作研究計畫國外研究報告書一份

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行政院國家科學委員會專題研究計畫成果報告

通信用超快光偵測器

Ultrahigh-speed photodetector for optical communication

計畫編號：NSC88－2218－E－002－038

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一、中文摘要

本計畫提出光通信用高速傳導波光偵測器之設計、製作、與量測。

在實驗系統架設方面，本計畫於第一年度即已完成飛秒鉻：貴橄欖石雷射系統之架設。此雷射系統為目前全台唯一之飛秒鉻：貴橄欖石雷射系統。本計畫於第二年度時完成光電取樣系統，此系統為全世界唯一一套以飛秒鉻：貴橄欖石雷射驅動之光電取樣系統，頻寬超過一兆赫。

在實驗結果方面，本計畫於三年執行期間完成下列成果：

(1) 世界紀錄頻寬光偵測器之設計與製作：本計畫提出之金屬-半導體-金屬傳導波光偵測器，在 800nm 波長之頻寬超過 570GHz，為目前已知最寬頻之光偵測器。

(2) 世界紀錄頻寬-功率乘積光偵測器之設計與製作：本計畫提出之金屬-半導體-金屬傳導波光偵測器，在 800nm 波長之頻寬-功率乘積超過 4.4THz-V，為目前已知最高之頻寬-功率乘積。

(3) 超寬頻通信波長光偵測器之設計與製作：本計畫提出之金屬-半導體-金屬傳導波光偵測器，在 1300nm 波長之頻寬超過 240GHz，為目前已知最寬頻之通信波長光偵測器之一，其通信波長頻寬-功率乘積超過 568GHz-V。

(4) 研究光偵測器飽和行為，提出完整物理模型。

(5) 提出漸變式分布光偵測器。

(6) 設計出 12 波長輸出，皮秒脈衝高功率通信波長固態雷射。

(7) 設計出腔內倍頻飛秒鉻：貴橄欖石雷射。

(8) 提出新飛秒脈衝量測技術：三階自相干量測。

關鍵詞：光偵測器、頻寬-功率乘積、鉻：貴橄欖石雷射、光電取樣系統、三階自相干量測

Abstract

This project focused on design, fabrication, and measurement of ultrahigh bandwidth photodetectors for telecommunications.

For the system construction, we have built up a new femtosecond Cr:forsterite laser system under the NSC support during the first year of this project. This laser is currently the only femtosecond Cr:forsterite laser system in Taiwan. During the second year, we have built an electro-optical sampling system based on the Cr:forsterite laser. This electro-optical sampling system is the only system based on a Cr:forsterite laser in the world. Its sampling bandwidth is over 1 THz.

For the experimental part, we have obtained the following results with this project:

(1) Design and fabrication of a world-record bandwidth photodetector. In this project, we proposed a novel metal-semiconductor-metal traveling-wave photodetector. After fabrication, its measured bandwidth at 800 nm is over 570GHz, a new world record.

(2) World-record bandwidth-power product photodetector. Our proposed photodetector exhibits great bandwidth-power product of 4.4 THz-V, also a new world record.

(3) Design and fabrication of ultra-high bandwidth photodetectors at telecommunication wavelength. Our novel metal-semiconductor-metal traveling-wave photodetector achieved an ultrahigh bandwidth of 240 GHz at 1300 nm telecommunication wavelength, which is one of the highest bandwidth photodetector in the world. At telecommunication wavelength, its bandwidth-power product also exceeds 568 GHz-V.

(4) Proposed a complete model for bandwidth saturation behavior in ultrahigh bandwidth photodetector under high illumination.

(5) Proposed a novel Taper-Line Distributed Photodetector.

(6) Designed a 12-wavelength output, picosecond pulsewidth, high-power solid state laser for telecommunication.

(7) Designed an intra-cavity frequency-doubled femtosecond Cr:forsterite laser.

(8) Proposed a novel pulse measurement technique: Third-Order-Autocorrelation for Direct

pulseshape measurement (TOAD).

Keywords: photodetector, bandwidth-power product, Cr:forsterite laser, electro-optical sampling system, third-order-autocorrelation.

二、計畫緣由與目的

本計畫為國際合作計畫，合作對象為美國 University of California at Santa Barbara 之 Prof. John Bowers。Prof. John Bowers 在超快光偵測器方面極具威望。本計畫之目的在提出光通信用高速傳導波光偵測器之設計、製作、與量測。設計與量測由我方全權負責，長晶由美方負責，製程則由我方派博士班研究生至 University of California at Santa Barbara 利用美方設備完成。

本實驗室在計畫中提出一新型光偵測器：金屬-半導體-金屬傳導波光偵測器。在以低溫成長砷化鎵為主動區時，此光偵測器由於缺乏參雜區，因此其微波性質極為優異。其微波傳播速度亦高於光速，因此為一真正之傳導波光偵測器。藉由低溫成長砷化鎵中載子生命期短之特性，此光偵測因此具有極寬之頻寬與極高之輸出飽和功率。利用其雜質至導帶區之電子躍遷特性，此偵測器亦可應用於通信用長波長(1.3-1.55 毫米)。

在計畫執行期間，計畫主持人(孫啟光)在國科會國合處補助下，共赴美六次(每年寒暑假各一次)。本計畫項下博士班研究助理(許晉瑋)亦在國合處補助下，共赴美兩次。相關邀訪活動執行成果報告，已於每次活動結束後，另案向國合處提出。

三、結果與討論

在本計畫執行期限內，因受本計畫之經費贊助，完成下列事項(部分經費由台大補助)：

(A) 實驗系統架設方面:

1. 完成飛秒鉻：貴橄欖石雷射系統之架設

   波長輸出範圍為 1220-1270 nm，功率為 350 mW，脈衝寬度約為 80-150 fs。此雷射系統為目前全台唯一之飛秒鉻：貴橄欖石雷射系統。發表論文請見計畫成果自評：論文 (A)6。

2. 設計出 12 波長輸出，皮秒脈衝高功率通信波長固態雷射。

   基於所架設之飛秒鉻：貴橄欖石雷射系統，本計畫以腔內 etalon 控制，完成 12 波長輸出，皮秒脈衝高功率雷射，每一輸出波長之功率在 1-50mW 間，脈衝寬度在 1.5-20 ps。為目前多波長輸出雷射功率最高者。發表論文請見計畫成果自評：論文 (A)4、(A)11、(B)I11、(B)I14。

3. 設計出腔內倍頻飛秒鉻：貴橄欖石雷射

   基於所架設之飛秒鉻：貴橄欖石雷射系統，本計畫以腔內倍頻，完成橘光波長輸出，飛秒脈衝高功率雷射，輸出功率在 30mW，脈衝寬度在 200 fs。此雷射為已知之唯一橘光波長輸出、飛秒固態雷射。發表論文請見計畫成果自評：論文 (A)3、(B)I15。

4. 提出新飛秒脈衝量測技術：三階自相干量測

   為能完全了解飛秒鉻：貴橄欖石雷射輸出之波型，本計畫提出三階自相干量測技術。此技術為目前唯一可以時域技術完全決定脈衝形狀。結合頻譜輸出，亦可完全決定脈衝相位分布。此技術目前正申請美國專利中。發表論文請見計畫成果自評：論文 (A)9、(B)I19。

5. 完成光電取樣系統

   基於飛秒鉻：貴橄欖石雷射，本計畫完成通信波長元件之光電取樣系統，頻寬超過一兆赫。此系統為全世界唯一一套以飛秒鉻：貴橄欖石雷射驅動之光電取樣系統。此系統相較於其他系統，具有寬頻、穩定、高功率之優點。

(B) 實驗結果方面:

1. 世界紀錄頻寬光偵測器之設計與製作：

   本實驗室在計畫中提出一新型光偵測器：金屬-半導體-金屬傳導波光偵測器。在以低溫成長砷化鎵為主動區時，此光偵測器由於缺乏參雜區，因此其微波性質極為優異。其微波傳播速度亦高於光速，因此為一真正之傳導波光偵測器。藉由低溫成長砷化鎵中載子生命期短之特性，此光偵測因此具有極寬之頻寬。在 800nm 波長刺激下，以光電取樣系統量測之頻寬超過 570GHz，為目前已知最寬頻之光偵測器。發表論文請見計畫成果自評：論文 (A)5、(B)I2、(B)I10、(B)I18。

2. 世界紀錄頻寬-功率乘積光偵測器之設計與製作：

   本計畫提出之金屬-半導體-金屬傳導波光偵測器，藉由低溫成長砷化鎵中載子生命期短之特性，此光偵測因此亦具有極高之飽和頻寬。在強光照射下，在 800nm 波長可輸出 20V 之電壓，且可達 220GHz

之頻寬，其頻寬-功率乘積超過4.4THz-V，為目前已知最高之頻寬-功率乘積。發表論文請見計畫成果自評：論文(A)12、(B)I23。

3. 超寬頻通信波長光偵測器之設計與製作：

藉由低溫成長砷化鎵中雜質至導帶區之電子躍遷特性，低溫成長砷化鎵偵測器亦可應用於通信用長波長(1.3-1.55 毫米)。本計畫提出之低溫成長砷化鎵金屬-半導體-金屬傳導波光偵測器，特殊長波長設計後，在1300nm波長光電取樣系統量測之頻寬超過240GHz，為目前已知最寬頻之通信波長光偵測器之一，且其通信波長頻寬-功率乘積超過568GHz-V。此光偵測器之表現，已超過計畫目標。發表論文請見計畫成果自評：論文 (A)8。

4. 研究光偵測器飽和行為，提出完整物理模型：

為能在超快光偵測器中達到高功率輸出，光偵測器飽和行為之了解至為重要。本計畫提出一完整物理模型以描述光偵測器飽和行為。發表論文請見計畫成果自評：論文(A)1、(B)I1。

5. 提出漸變式分布光偵測器：

未能更進一步提高輸出功率與頻寬，本計畫亦提出一新型光偵測器結構：漸變式分布光偵測器(Taper-Line Distributed Photodetector)。經由漸變之阻抗匹配，以充分利用反射波，達到提升功率與頻寬之雙重目的。發表論文請見計畫成果自評：論文(A)10。

四、計畫成果自評

本計畫已完成當初預期之目標。在論文方面則已發表期刊論文共7篇，國際會議論文23篇，國內會議論文11篇，另有1篇論文已被接受，4篇論文已投稿尚在審查中。

(A) SCI 期刊論文

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(B) 研討會論文

I. 國際會議論文

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