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14. ABSTRACT
The DURIP funding was used for the acquisition of a cryogenic optoelectronic probe station (COPS). The system has been installed and fully functional as expected. Various combinations with other existing setups have been tried. Successful experimental results using the COPS system have been obtained.

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Report Title

Cryogenic Optoelectronic Probe Station

ABSTRACT

The DURIP funding was used for the acquisition of a cryogenic optoelectronic probe station (COPS). The system has been installed and fully functional as expected. Various combinations with other existing setups have been tried. Successful experimental results using the COPS system have been obtained.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

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TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Paper

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME PERCENT_SUPPORTED

FTE Equivalent:

Total Number:

Names of Post Doctorates

NAME PERCENT_SUPPORTED

FTE Equivalent:

Total Number:

Names of Faculty Supported

NAME PERCENT_SUPPORTED

FTE Equivalent:

Total Number:

Names of Under Graduate students supported

NAME PERCENT_SUPPORTED

FTE Equivalent:

Total Number:

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period:	0.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:......	0.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:......	0.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):	0.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:	0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense	0.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:	0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED

FTE Equivalent:

Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Technology Transfer

Cryogenic Optoelectronic Probe Station (COPS) System: Final Report

The DURIP funding was used for the acquisition of a cryogenic optoelectronic probe station (COPS). The system has been installed and fully functioning as expected. Various combinations with other existing setups have been tried. Successful experimental results using the COPS system have been obtained.

Basic Capability

Our cryogenic optoelectronic probe station (Lake Shore, model TTPX) is capable of measurement in a wide temperature range from 4.5K to 475K. Unlike most other COPS which only have four probe arms, our COPS consists of six probes arms. All of the probe arms are ultra-stable, micromanipulated, each providing precise 3-axis probe position control to land the probe tip accurately on device features. Four of the arms are equipped with electrical probes which not only can be used for electrical injection but also capable of doing a standard four-point probe measurement to determine electrical transport properties such as conductivity and I-V curve. All of the probes can be used for low-noise, high-impedance electrical measurements. Additionally, the other two arms are

Fig.1 TTPX cryogenic optoelectronic probe station

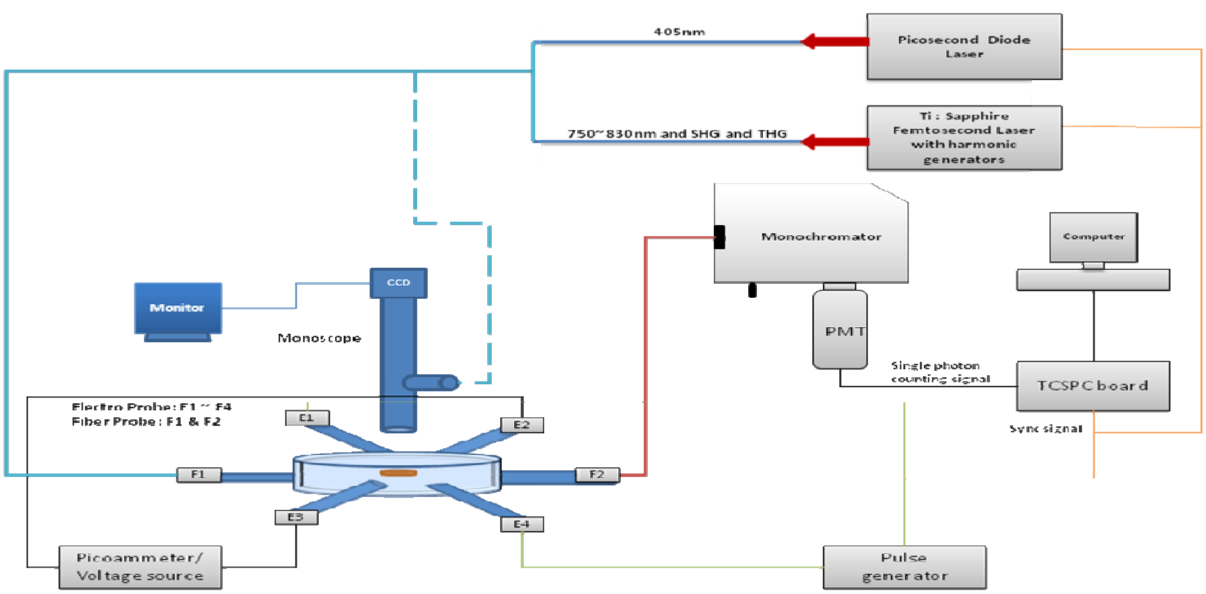

Fig.2 Schematic setup of COPS in conjunction with other instrument for time-integrated and time-resolved optical measurements with varying temperature capability and for two dimensional scanning

configured as fiber probes, which could be used for laser excitation and collection of emitted light (e.g., PL or lasing). The Edmund 16X precision zoom lens system working with a Mitutoyo objective allows a 2-μm spatial resolution while still maintain a large working distance. The OPTEM 70XL zoom system allows a NIR observation. Our COPS is also fully compatible with other existing lasers and detectors so that the overall capability of our lab is now greatly expanded. As an example, Fig.2 shows schematic of integrating the COPS with other existing time-resolved or time-integrated photoluminescence measurements to obtained time or spectral resolved two dimensional scanning measurements. All these unique features make our COPS a powerful tool for a variety of nanophotonics characterization. Such capability is very important for a few on-going projects under DOD support.

Selected Examples of Research Using COPS

Example 1: sheet resistance measurement using four-point probe

We have fabricated some Indium doped ZnS thin film for an N type contact material. In order to figure out the effective donor concentration of this thin film contact material, we need to know the sheet resistance. As shown in Fig. 1, four electric probes are landed onto the surface of the thin film at an equal distance of 5 mm. When 10 V is applied between probe 1 and 4, we get a current of 80.4 nA and a voltage of 62.4 mV across probe 2 and 3. Therefore we can determine the sheet resistance by using Eq: $R_{sheet} = \frac{\pi}{\ln(2)}\frac{V_{23}}{I}$. This gives the sheet resistance of 3.52 MΩ/□ and indicated that the effective donor concentration is around 10^{16} cm^{-3}.

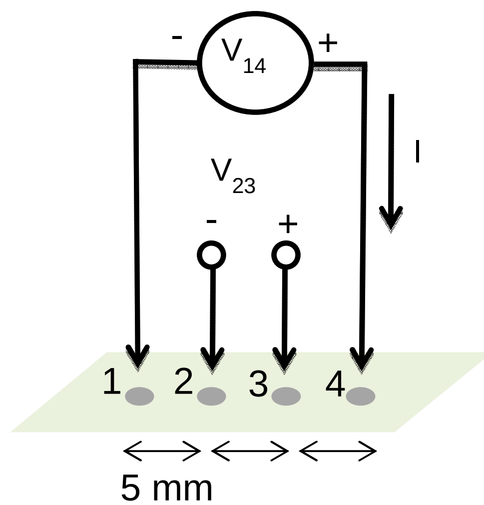

Figure 3 Four-point probe configuration for sheet resistance measurement.

Example 2: Electroluminescence and I-V curve measurement of nanolaser device under low temperature

One of great advantages of COPS is that it allows us to perform electrical injection luminescence or lasing study of nanowires and nanopillars without complicated fabrication processes. As an example, we use COPS to measure the I-V curve of fabricated nanolaser devices before wire bonding. Due to the difficulty of doing wire bonding and the possibility of causing damage to the nanolaser device, COPS provides us a quick and safe fashion of testing the IV property of the devices. With the optical probe, we can even collect the EL signal of the device. Fig. 4(a) shows a nanolaser device under test. The device is forward biased under two electric probes. One optical probe on top of the device collects the emission light and then coupled to a spectrometer. The entire system is cooled down to 78 K. Fig. 2(b) shows the corresponding IV curve and emission intensity at different injection current. A clear lasing behavior can be observed with a lasing threshold around 400 μA.

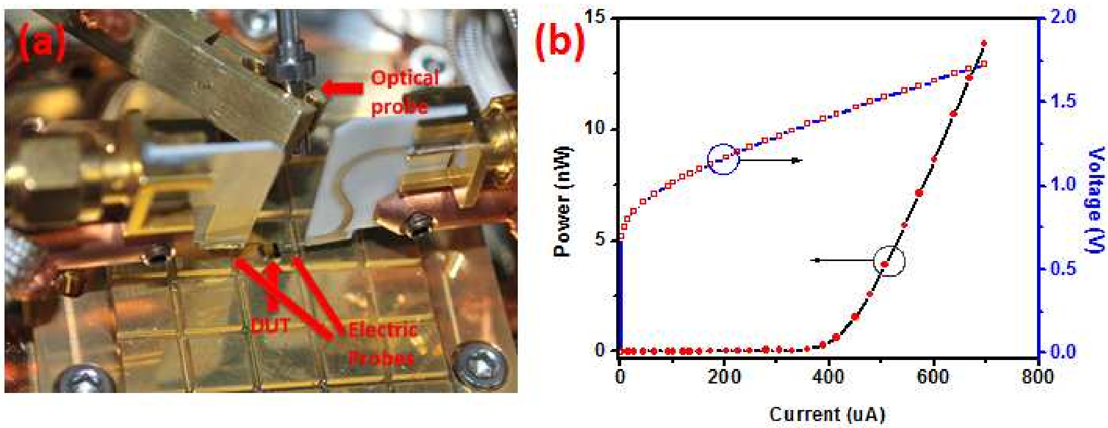

Figure 4 (a) A nanolaser device under test (DUT). (b) I-V curve and emission power under different injection current.