• Physics, Medical Physics and Pre-Engineering department

- LAMS center Laser Ablation and Materials Science center 11, 12, 13, 14, 15, 16, 17
- The LAMP center Laser Ablation and Materials Science center contains the state – of-art- film fabrication chambers which are invented and patented by Professor Darwish. The systems are explained as concurrent multi-targets-multi lasers PLD systems which can produce a nanocomposite then film fabricated from 6 inorganic targets and one organic target though matrix assisted plused laser evaporation (MAPLE) system. For the first time ever, both PLD and MAPLE are existing in one chamber.
- Multiple projects funded from the US Air Force Office of Scientific Research and the Army Research office to support students paid-hands-on research activities during the academic year and summer. Scholarship is available for qualified students.

Research Projects funded by AFOSR, ARO,NIH, NIST, DOE and IBM in nanocomposite materials and thin film fabrication by laser ablation

1 Polymer nanocomposite luminescent spectrum convertors for photovoltaic energy harvesting

Abdalla M. Darwish, Dillard University, New Orleans, LA,

Polymer nanocomposite luminescent spectrum convertors for photovoltaic energy harvesting

STATUS QUO

Luminescent solar concentrators (LSCs)

- LSCs are large polymer/glass plates filled/coated with luminophores that absorb the sun light and re-emit it at longer wavelength
- the plate-light guide redirects the re-emitted radiation to edge-attached photovoltaic (PV) cells to generate electricity.

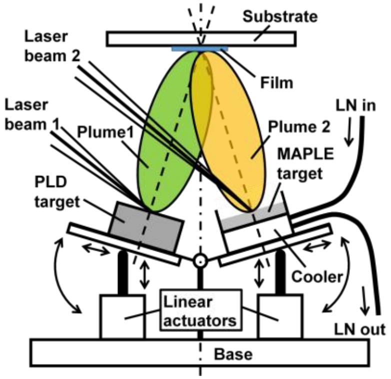
Deficiencies

Use of LSCs is hindered by the lack of suitable luminophore coatings • the available ones have a large overlap between the absorption and emission spectra, which leads to strong reabsorption of the guided luminescence.

NEW INSIGHTS

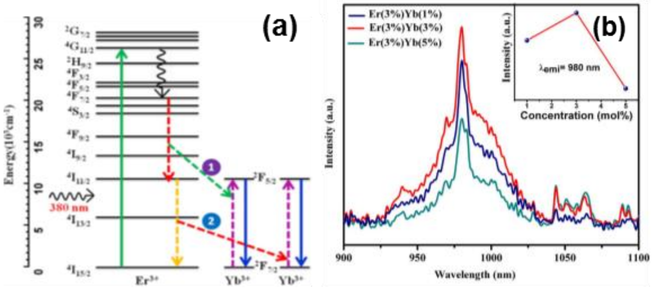
Polymer nanocomposite luminophore coatings

- Polymer nanocomposite LSC films of polymer PMMA with the nanoparticles of downconverison phosphor $NaYF_4:Yb^{3+},Er^{3+}$ will be deposited on window glass • the concurrent multi-beam multi-target pulsed laser deposition and matrix assisted pulsed laser evaporation (MBMT-PLD/MAPLE) in ambient air will be used.



Schematic of the deposition system

MAIN ACHIEVEMENTS:



(a) Energy diagram of Er^{3+} and Yb^{3+} ions in polymer PMMA film with the nanoparticles of $NaYF_4$:Yb,Er shows down conversion of the UV sun light. (b) NIR emission spectra (900 –1100 nm) of NaYF4:Yb,Er phosphor. Inset: 980 nm emission intensity versus Yb^{3+} concentration.

- Design, building, and testing of the three-beam three-target MAPLE/PLD deposition system • demonstration of a polymer nanocomposite film with downconversion phosphor • demonstration of the spectrum downconversion capabilities of the phosphors with reduced re-absorption overlapping for LSCs.

HOW IT WORKS:

- Polymer matrix is deposited by MAPLE using the beam from a 1064-nm Q-switched Nd:YAG laser • inorganic phosphor nanoadditive is concurrently deposited by PLD using 532-nm beams • overlapping of the plumes from the targets is achieved by the remote control of target tilt • the phosphor is synthesized using the wet method • the phosphor is reduced in the nanopowder by the ball milling process.

ASSUMPTIONS AND LIMITATIONS:

- Inorganic material will preserve its properties during its transfer to the polymer • Polymer solution target must be frozen.

QUANTITATIVE IMPACT

Current impact

- LSCs are tested in terms of their Power Concentration Factor (PCF) of the light simulating Air Mass (AM) 1.5 global spectrum • PCF of the samples coated with pure PMMA is ~ 2-3.

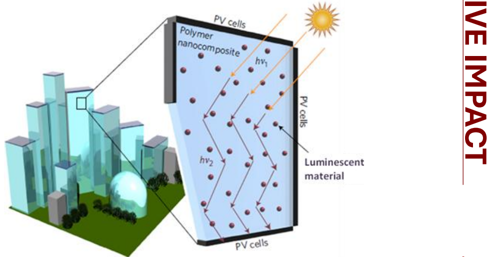


Diagram shows the concept of the luminescent solar concentrator (LSC). The particles of a luminescent material absorb incident sunlight (orange arrows; $h\nu_1$) and re-emit the light at a longer wavelength (red arrows; $h\nu_2$) in the doped/coated LSC polymer/glass plate.

Planned impact

- PCF of the LSC films deposited in open air will be at least 90% of that of the films made in vacuum. To upgrade the multi-beam multi-target system by incorporating a femtosecond laser • PCF of the films will be 10 or higher (> 3 times greater than pure PMMA).

END GOAL

Research goal

To verify the hypothesis that polymer nanocomposite films doped with nanoparticles of rare-earth (RE)-doped fluorides and deposited using the open-air pulsed-laser deposition (PLD) will function as efficient (LSCs).

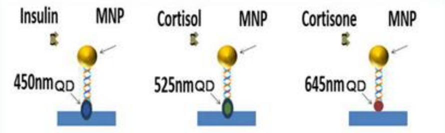
BEITA

National Institute of Biomedical Imaging and Bioengineering

Technologies to Shape the Future of Health

Phase	Duration	Biomarker	Innovation	Platform	Detection
I. UG3: planning & initiation	2025-28	cortisol, cortisone, insulin physiologic concentration in buffer solutions	binder; fluorophore; chromophore	MoS_2-Au*	SERS; fluorometric; colorimetric
				QD-Au**	time-/spectral-PL
II. UH3: implementation	2028-32	cortisol, cortisone, insulin from biological samples (Saliva, Urine, Blood from human subjects)	binder; fluorophore; chromophore	MoS_2-Au†	SERS; fluorometric; colorimetric
				QD-Au†	time-/spectral-PL

*To be developed at JSNN/Dillard. **To be developed at UAH/Dillard. †To be developed at WSSU



Schematic representing three (3) functionalized QDs to selectively detect insulin, cortisol, and cortisone.

2 Photonic nanocomposite films made by pulsed laser deposition

Abdalla M. Darwish

Kick-off presentation

STATUS QUO

Deficiencies of current short-wavelength sensors

- Silicon-based optoelectronic sensors are not capable of sensing short-wavelength radiation
- Spectrum down-converting photoluminescent (PL) materials adapt Si sensors to short-wavelength radiation.
- Embedded metal nanoparticles (NPs) can enhance PL due to the surface plasmon polariton (SPP) resonance.

NEW INSIGHTS

High-entropy alloy nanoparticles (HEA NPs)

Tuning SPP resonance can be achieved by mixing several metals in the NP.

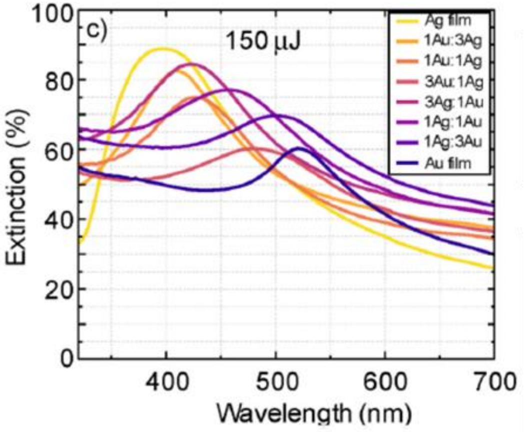


Fig. 1. Optical extinction spectra of the nanoparticles of Ag, Au, and bimetallic (Ag/Au) prepared by laser ablation in water [Petrikaite et al. Opt Mater 137 (2023) 113535].

Project objectives:

The goal is to verify the hypothesis that bringing HEA NPs in the down-converting nanocomposites will improve the intensity of their photoluminescence (PL).

Objectives:

1. Obtaining constituent materials and making PLD targets and their characterization.
2. Making nanocomposite films using CMBMT PLD method.
3. Characterization of the produced nanocomposite films.
4. Data analysis and conclusions on reaching the goal.
5. Training African-American minority students through participation in the project.

Approach:

Step 1

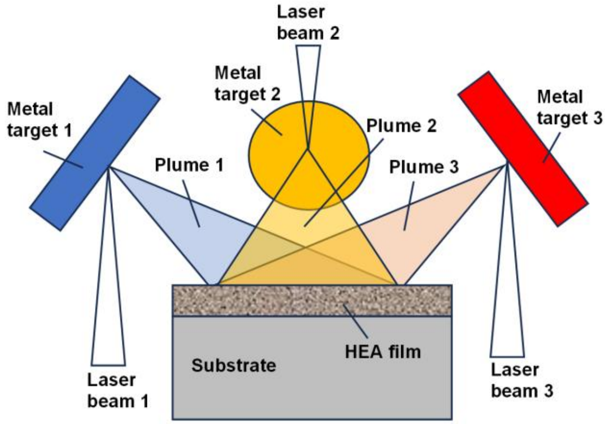


Fig. 2. Step 1. CMBMT-PLD deposition of HEA film. HEA could be made of plasmonic noble metals Ag, Au, Cu and transitional metals Al, Cr, Ni, Pt, and Ti.

QUANTITATIVE IMPACT

Step 2

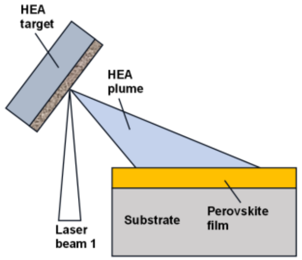


Fig. 3. Step 2. Making perovskite down-converting nanocomposite embedded with HEA NPs. Pure perovskite film was initially PLD deposited.

Step 3

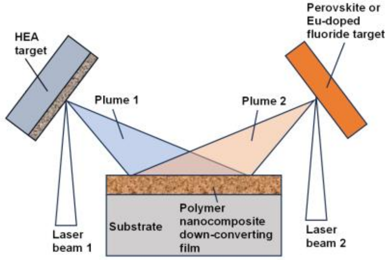


Fig. 4. Step 3. Making down-converting polymer nanocomposite embedded with the NPs of HEA, perovskite or Eu-doped fluoride.

Step 4. Measuring improvement of the intensity of down-conversion PL of the nanocomposite films impregnated with HEA NPs versus the films without HEA NPs.

END-OF-PHASE GOAL

Expected results

Manifold improvement of the down-conversion PL intensity due to SPP resonance introduced by HEA NPs.

3 Ultaviolet spectrum downshifting in polymer nanocomposite films for performance improvement of solar cells

Abdalla M. Darwish, Dillard University

STATUS QUO

Background

- Photoelectronic devices, such as photovoltaic solar cells suffer from solar UV radiation.
- We propose to use polymer nanocomposite spectrum downshifting films to protect solar cells and improve their conversion efficiency.
- A spectrum converting (downshifting) layer (SCL) can be placed over a solar cell to convert UV radiation into extra visible/NIR light matching the spectral responsivity of the cell (Fig. 1).
- The PV cell turns this visible/NIR light into extra electricity.
- The layer also protects PV cell from UV and extends its operational lifetime.

NEW INSIGHTS

Proposed technology

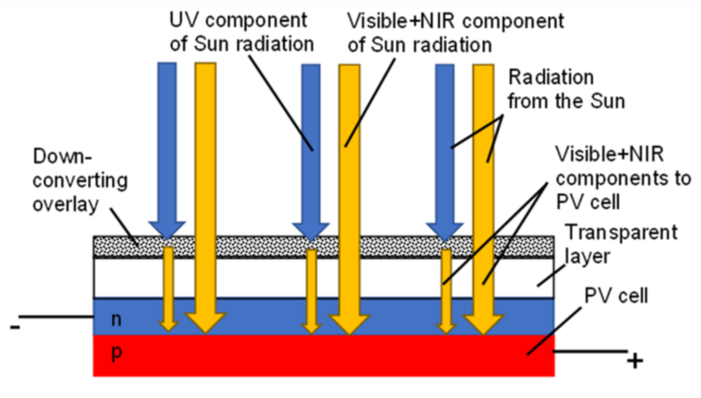


Fig. 1. Schematic illustrating the concept of a sunlight UV spectrum converting layer (SCL) over a photovoltaic (PV) cell. SCL in the form of spectrum down-converting overlay absorbs incident UV sunlight and converts it in visible and NIR radiation that efficiently generates extra electrical power in addition to the one produced by visible and NIR spectral components of sunlight. Additionally, it protects PV cell form harmful UV and extends it lifetime.

1. Synthesis of spectrum down-shifting nanoparticles (NPs) of $NaYF_4$: Eu^{3+}.

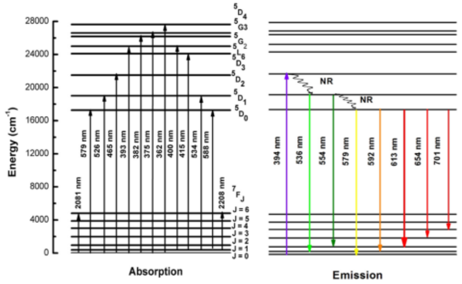


Fig. 2. Energy level diagram of Eu^{3+} illustrating the mechanism of spectrum down-shifting: single UV photon produces single visible/NIR photon.

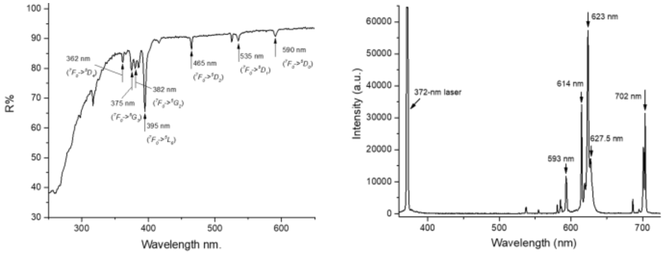


Fig. 3. Left: Diffusion reflectance spectrum of the powder of $NaYF_4$: Eu^{3+} (60% Eu). Right: Photoluminescence (PL) spectrum of the powder $NaYF_4$: Eu_{3+} (90% Eu) NPs pumped by a 372-nm UV diode laser Oxxius (7 mW). Photoluminescence quantum yield ~ 60%.

2. Polymer host

We selected space and low-orbit tested polymer CORIN from Nexolve.

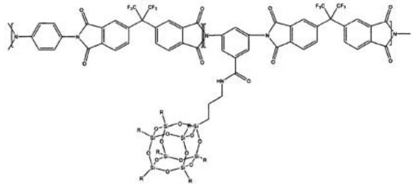


Fig. 4. Chemical formula of the chain link CORIN colorless polyimide polymer with tethered oligomeric silsesquioxan (OS) unit connected with an amide obtained from Nexolve (US Pat. 7,619,042 B2). The polymer is designed for low-orbit space applications and is durable to ozone.

QUANTITATIVE IMPACT

3. Performance testing

We performed performance testing of the SCL.

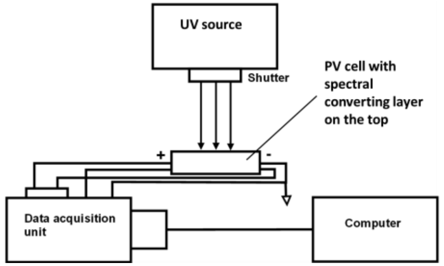


Fig. 5. Block diagram of the experimental setup for measuring I-V characteristics of the spectrum converting layer over a PV cell.

We investigated SCL integrated with three types of PV cells: consumer grade Si, and flexible CIGS and IMM cells.

4. Results

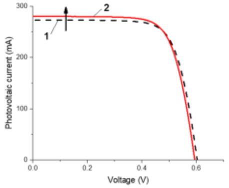


Fig. 6. I-V characteristics of consumer-grade Si cells coated with pure CORIN (curve 1) and the polymer nanocomposite SCL (CORIN + the NPs) before exposure to UV radiation. The improvement of photovoltaic short circuit current I_{SC} is by 2.54% and the generated PV power by 0.7%,

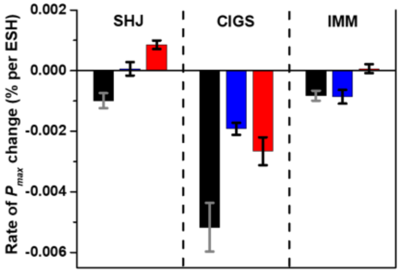


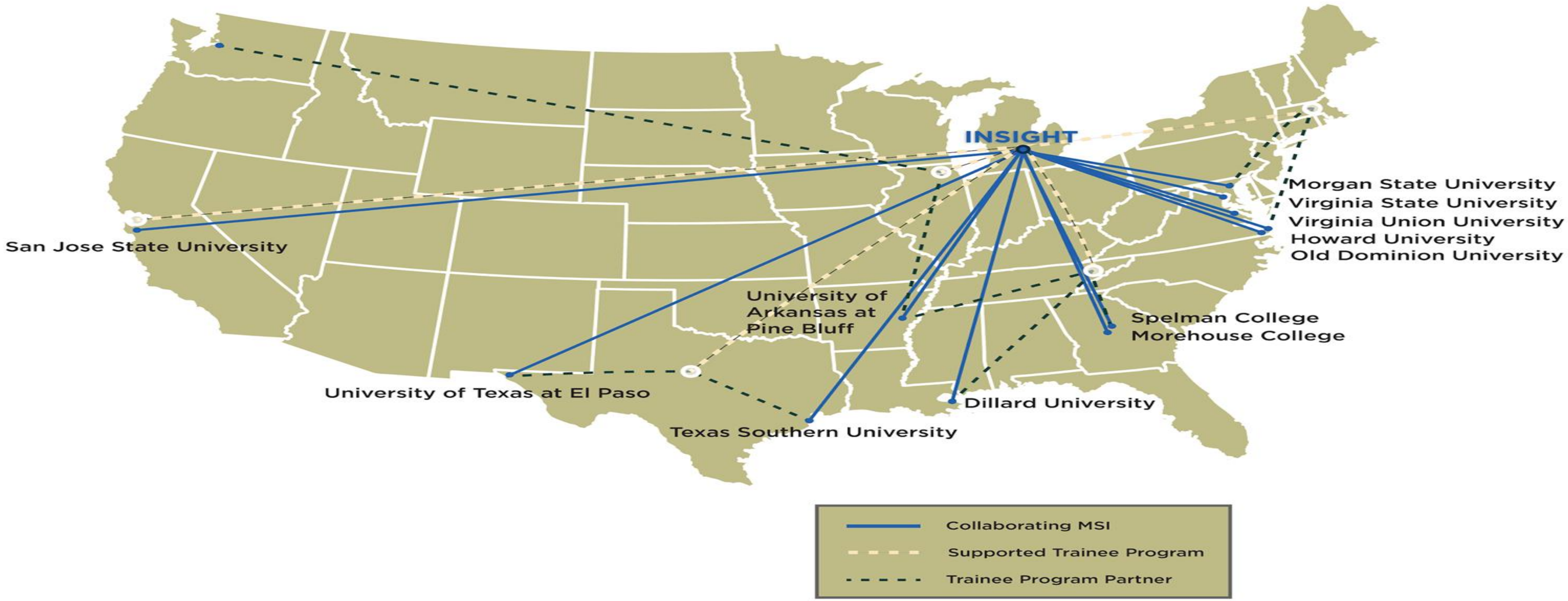
Fig. 7. The rates of the relative change of Pmax of the uncoated and coated solar silicon heterojunction (SHJ), copper indium gallium selenide (CIGS), and Inverted metamorphic multijunction (IMM) solar cell cells studied. Black bars - bare cells, blue – CORIN-coated, red – SCL-coated cells. The error bars are presented by thin gray/black lines.

CONCLUSIONS

Conclusions

- The improvement of UV stability by the spectrum converting layer was firmly (beyond the statistical spread) observed for all three types of solar cells.
- The degradation of the SHJ and IMM cells turned into zero or slight growth while the degradation of the CIGS decreased two-fold.

INSIGHT: Institute for Nuclear Science to Inspire the next Generation of a Highly Trained workforce



Summer outreach programs

DU QC WISHES
Dillard University Quantum Computing women in STEM
High school Experience in Summer program

REU photnic thin film fabrication by PLD for undergraduate students 10 weeks summer hands-on training

5 DU WISHES Women in STEM HIGH SCHOOL EXPERINCE SUMMER PROGRAM started in 2014 with 7, then the number increased to 23, to 45, to 70 and now it's 100 from across US supported by IBM and DAF

6 DU QC SFS WISHES Liquid nitrogen explosion

7 DU WISHES field trip to NASA

8 2023 DU WISHES cohort

9 IBM AFOSR

Women In STEM High School Experience in Summer "DU QC SFS WISHES" program summer since 2014

Vision and mission:

1. This outreach program is an initiative to continue encouraging black female high school (10th- 12th Grade) students to gain hands-on experience in STEM and Space Force related experiments and activities.
2. An exciting line-up of curriculum activities and explorations are planned that would excite and stimulate students' curiosity and critical thinking to Space Force science and Air Force mission and vision and workforce
3. Participants will learn about the illustrious minority women in science and Air Force and interact with our guest speakers

Impact of program on minorities Black Females in STEM

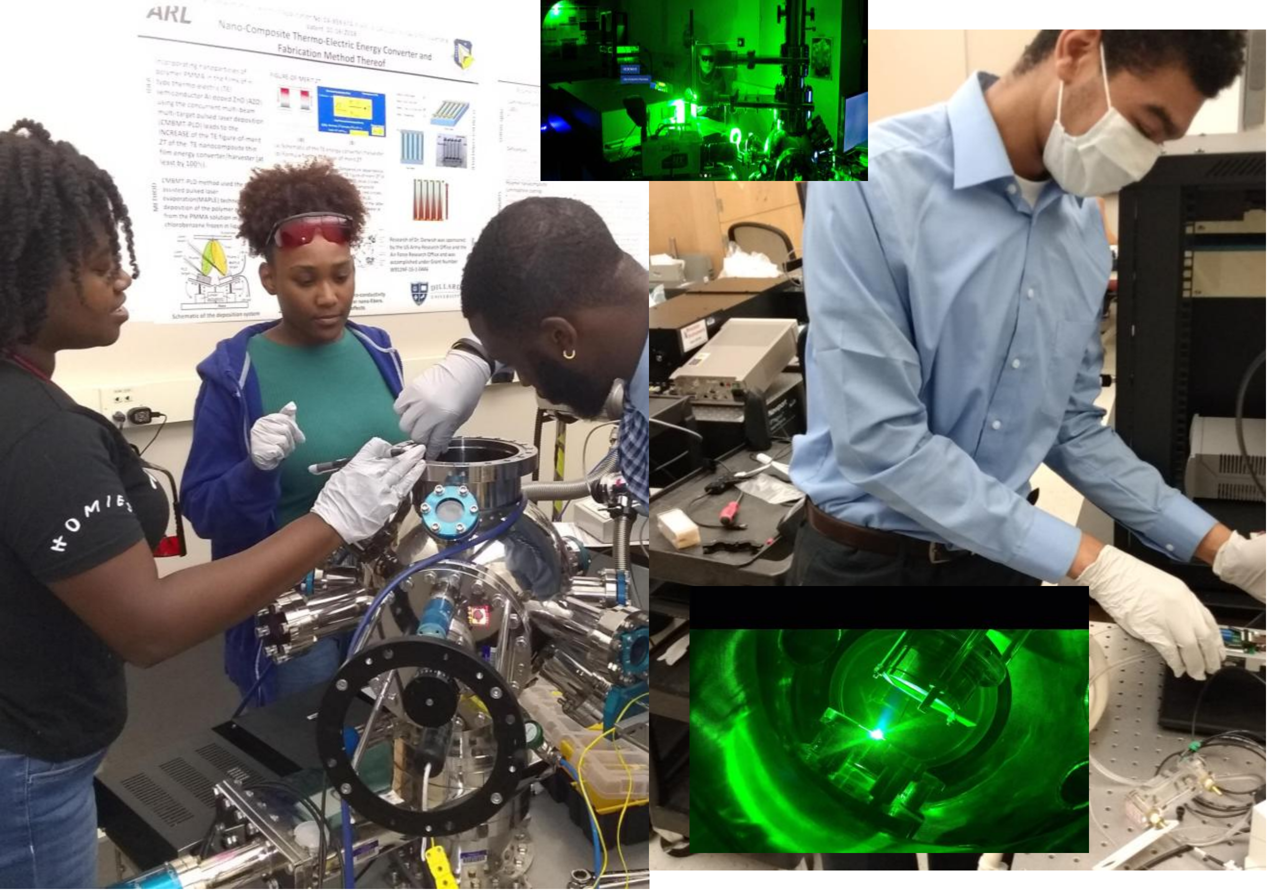
1. The AFOSR support, enabled STEM to increase the number of graduating black females in Physics at DU and enrolled to graduate programs (Forbes magazine)
2. The DU WISHES has huge impact on the community awareness about the mission and vision of DAF and Space Force science.
3. The curriculum activities of DU-WISHES is designed to give the scholars first glance of the science of Space Force and the hands-on training which is missing from the course education.

Targeting High schools in LA and other states disadvantage minorities and especially black females and college first generation and hands-on and minds-on training for workforce and pathway for future DAF cadets


Liquid nitrogen thermal expansion and space

Imapct on the University and physics department infrastructures

1. The physics department is equipped with state-of-the-art research infrastructure supported by AFOSR which will ensure a complete training of the HS minority scholars on lasers, optics, coding, rockets, jets and much more to achieve the mission of the program funding.



10 Louis Stokes Louisiana Alliance for Minority Participation (LS-LAMP)

Thanks to our STEM STEM faculty who made this program a success!!

- **The Louis Stokes Louisiana Alliance for Minority Participation (LS-LAMP) is one of 34 National Science Foundation Alliance Programs nationwide. This comprehensive, statewide coordinated program is aimed at substantially increasing the number and quality of minority students receiving baccalaureate degrees STEM and, subsequently, increasing the number of minority students entering graduate schools to earn doctoral degrees in STEM fields. The basic, statewide strategy is the replication and enhancement of exemplary mentoring and outreach programs. Thanks to all our STEM faculty.**

LAMS center

Laser Ablation and materials science center for fabrication of nanocomposite thin film for optical , biological and chemical sensors and wearble devices

12 Laser Ablation and Materials science (LAMS) center

- The LAMS center is built around the patents of Professor Darwish

5/7/2019

Dr. Abdalla Darwish, a Presidential Professor and Professor of physics at Dillard University, was awarded by USPTO with patent No US 10,283,691 B2 for his invention of NANO-COMPOSITE THERMO-ELECTRIC ENERGY CONVERTER AND FABRICATION METHOD THEREOF. The invention is a result of the research supported by and Air Force Office of scientific Research AFOSR Grant FA9550-12-1-0068 and US Army Grant W911NF -15-1-0446.

6/11/2019

Dr. Abdalla Darwish, professor of physics at Dillard University, was awarded by USPTO with patent No US 10,316,403 B2 for his invention of METHOD FOR OPEN-AIR PULSED LASER DEPOSITION. The invention is a result of research supported by US Air Force Grants No FA9550-12-1-0068 and W911NF -15-1-0446.

7/13/2021

The Presidential Professor, Dr. Abdalla Darwish, professor of physics at Dillard University, was awarded by USPTO with patent No US 11,059,128 B2 for his invention of MULTIPLE BEAM PULSED LASER DEPOSITION OF COMPOSITE FILMS. The invention is a result of the research supported by US Air Force Grants No FA9550-12-1-0068, and FA9550-18-1-0364.

13 NANO ADDITIVE MANUFACTURING USING MULTI-BEAM MULTI-TARGET PULSED LASER DEPOSITION OF NANOCOMPOSITE FILMS FOR PHOTONICS AND ENERGY HARVESTING Patents

Dr. Abdalla Darwish, Physics dept. Dillard University, New Orleans, LA10

Introduction

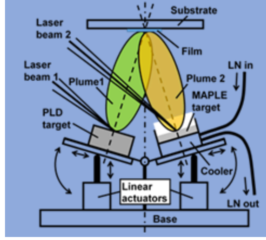
- Pulsed Laser Deposition (PLD) makes thin films of various materials with <1nm accuracy
- Concurrent multi-beam multi-target PLD (CMBMT-PLD) can make nanocomposite films with controllable distribution of the constituents with different properties

Methodology

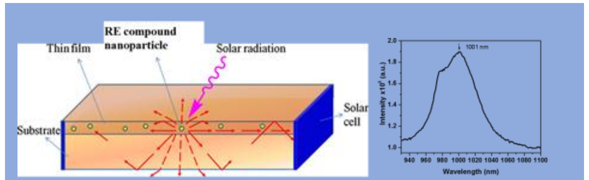
- Several laser beams (UV, VIS, IR) are used
- Several targets (inorganic & organic) are used
- Mixing proportion of the constituents in the film is controlled by the tilt of the targets to substrate.

Results

- US Patent No. 10,316,403 B2, **Method and apparatus for open-air pulsed laser deposition**, A. Darwish et al, 6/11/2019

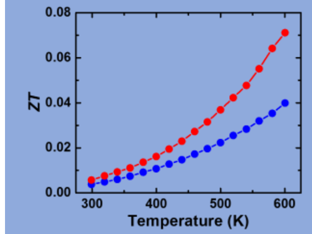


Schematic of the open-air PLD system.



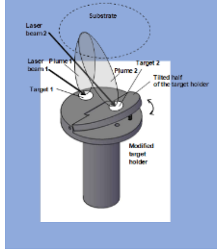
Schematic of the luminescent solar concentrator with polymer nanocomposite film made by open air CMBMT-PLD and its NIR spectrum after conversion of UV sun light.

- US Patent No. 10,283,691 B2 **Nano-composite thermo-electric energy converter and fabrication method thereof**, A. Darwish et al, 5/7/2019

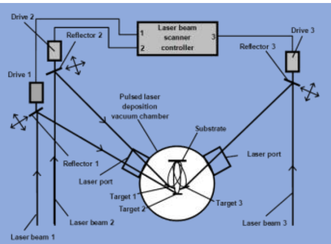


Embedding polymer nano-inclusions in Al-doped ZnO thin-film thermo-electric energy harvester (blue plot) using CMBMT-PLD doubled its figure-of-merit (red plot).

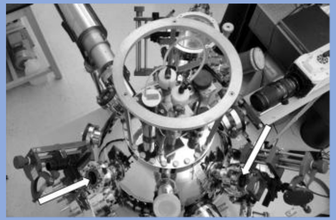
- US Patent No. 11,059,128 B2 **Multiple beam pulsed laser deposition of composite films**, A. Darwish et al, 7/13/2021



Schematic diagram of the modified double target holder. Target 2 has a variable tilt to provide overlapping of the plumes from both targets of the substrate.



Schematic of the concurrent multi-beam multi-target pulsed laser deposition (CMBMT-PLD) system at Dillard University that was used for additive manufacturing of polymer nanocomposite films.



General view of the CMBMT PLD system used to make the nanocomposite films. White arrows show two (out of three) optical windows of the 18-inch spherical vacuum chamber (in the center) for the laser beams..

Conclusions

- Open-air CMBMT-PLD can coat large surfaces.
- CMBMT-PLD can built nanostructures with 1-nm accuracy.
- Efficient solar spectrum convertors and thermo-electric energy harvesters can be made.

Acknowledgments:
AFOSR,ARO support of this research

11 laser Ablation and Material science LAMS center

DTPLD/MAPLE Fabrication & Characterization Flowchart

Analytic Instrumentation


RHEED


High-speed video camera 1Ms/sec

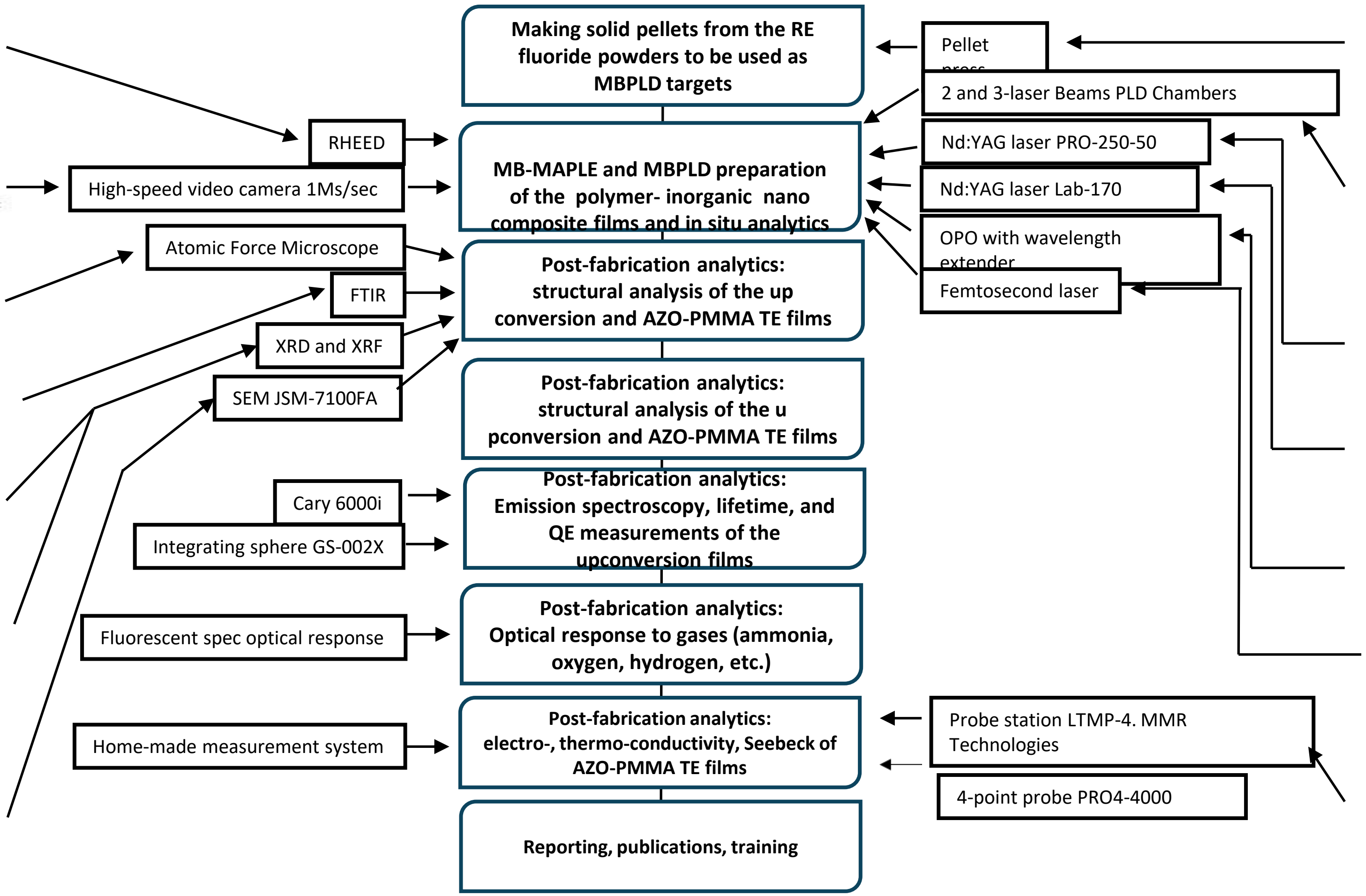

Atomic Force Microscope


FTIR


XRD


XRF


SEM JSM-7100FA



Making solid pellets from the RE fluoride powders to be used as MBPLD targets

MB-MAPLE and MBPLD preparation of the polymer- inorganic nano composite films and in situ analytics

Post-fabrication analytics: structural analysis of the up conversion and AZO-PMMA TE films

Post-fabrication analytics: structural analysis of the u pconversion and AZO-PMMA TE films

Post-fabrication analytics: Emission spectroscopy, lifetime, and QE measurements of the upconversion films

Post-fabrication analytics: Optical response to gases (ammonia, oxygen, hydrogen, etc.)

Post-fabrication analytics: electro-, thermo-conductivity, Seebeck of AZO-PMMA TE films

Reporting, publications, training

RHEED

High-speed video camera 1Ms/sec

Atomic Force Microscope

FTIR

XRD and XRF

SEM JSM-7100FA

Cary 6000i

Integrating sphere GS-002X

Fluorescent spec optical response

Home-made measurement system

Pellet press

2 and 3-laser Beams PLD Chambers

Nd:YAG laser PRO-250-50

Nd:YAG laser Lab-170

OPO with wavelength extender

Femtosecond laser

Probe station LTMP-4. MMR Technologies

4-point probe PRO4-4000

Processing Instrumentation


Pellet Press


2-Beam PLD Chamber / 3-beam PLD Chamber

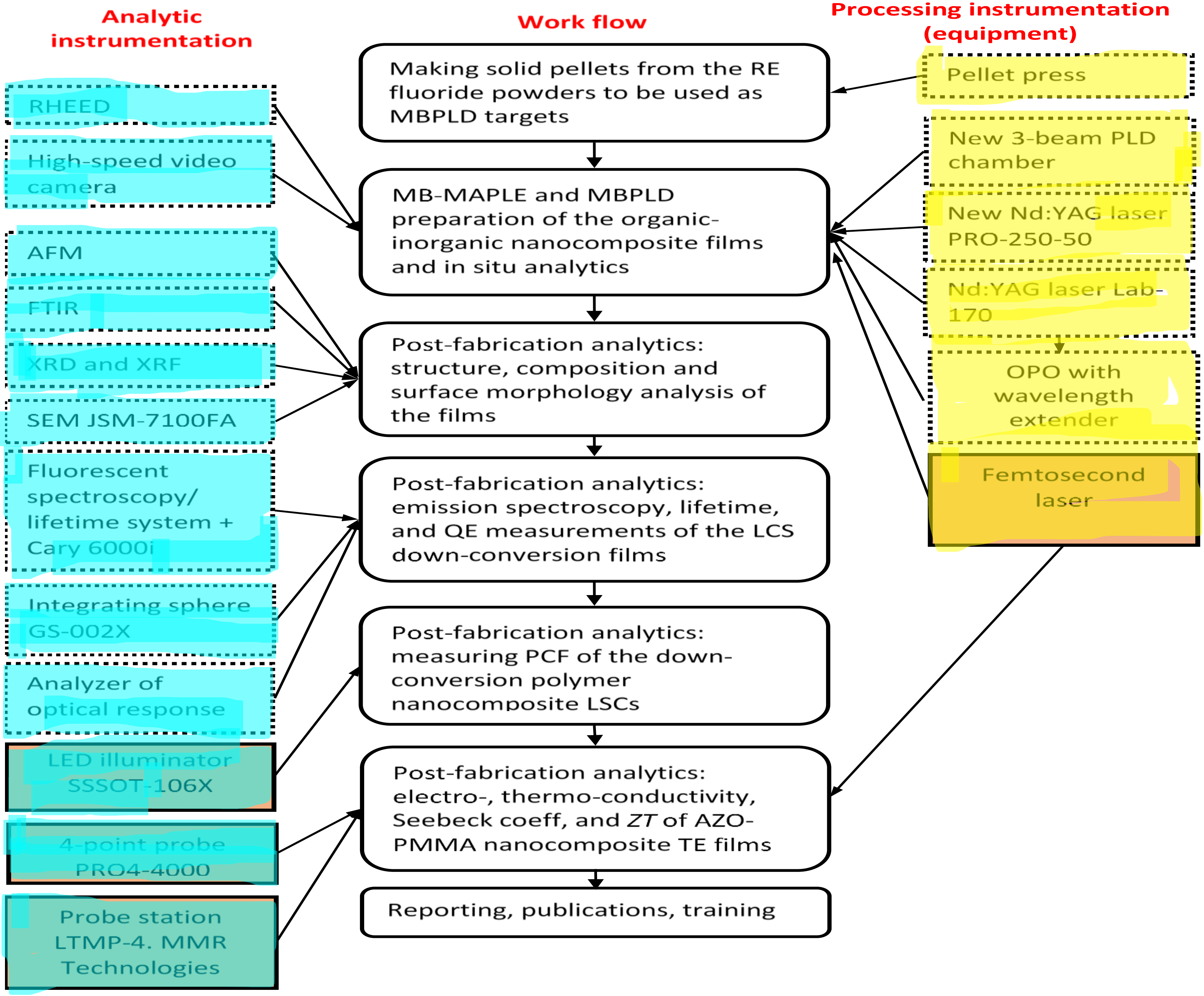

Nd:YAG laser PRO-250-50


Nd:YAG laser Lab-170


OPO with Wavelength Extender


Femtosecond


Probe station LTMP-4. MMR Technologies



Analytic instrumentation

- RHEED
- High-speed video camera
- AFM
- FTIR
- XRD and XRF
- SEM JSM-7100FA
- Fluorescent spectroscopy/ lifetime system + Cary 6000i
- Integrating sphere GS-002X
- Analyzer of optical response
- LED illuminator SSSOT-106X
- 4-point probe PRO4-4000
- Probe station LTMP-4. MMR Technologies

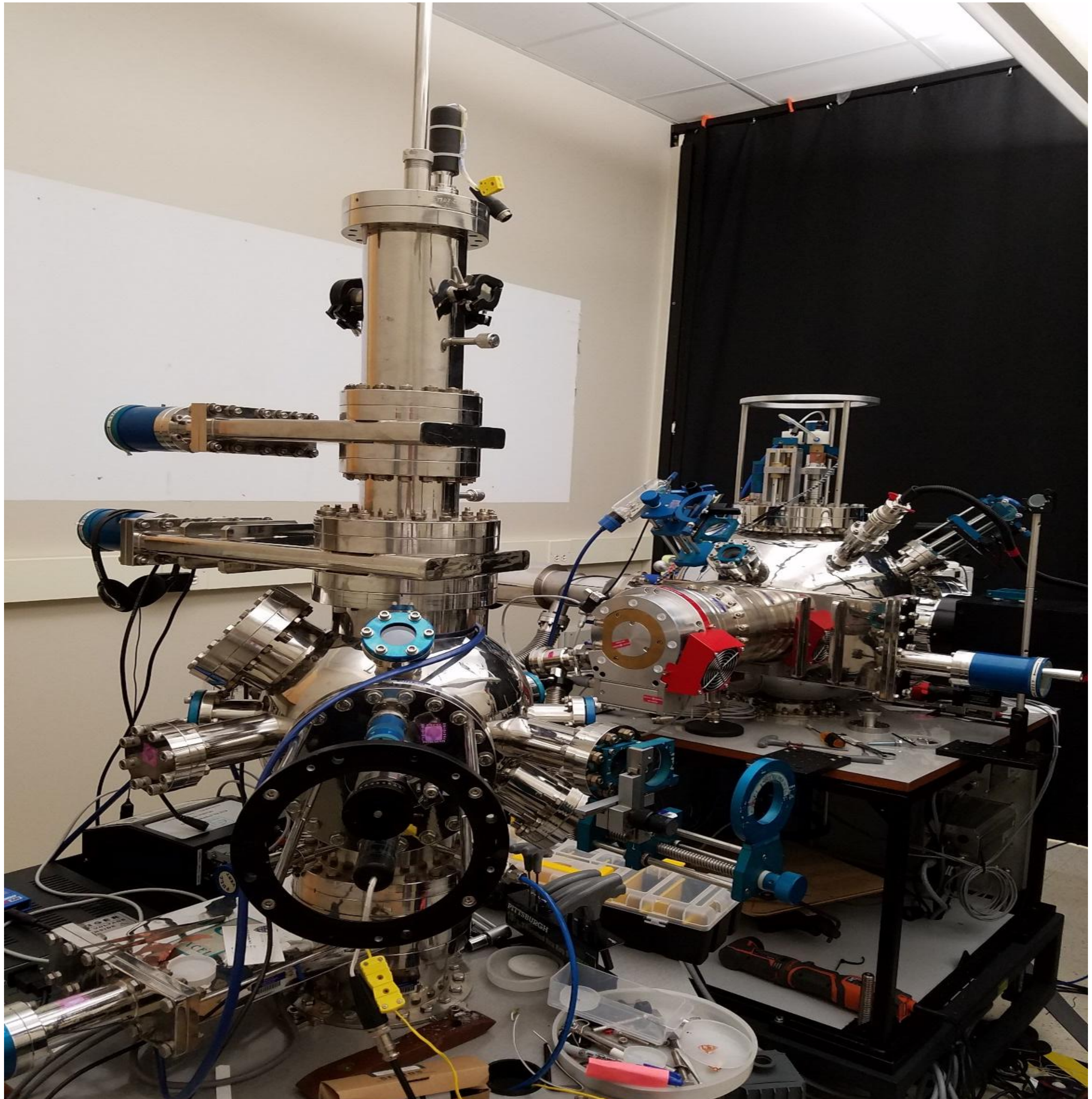
Work flow

- Making solid pellets from the RE fluoride powders to be used as MBPLD targets
- MB-MAPLE and MBPLD preparation of the organic-inorganic nanocomposite films and in situ analytics
- Post-fabrication analytics: structure, composition and surface morphology analysis of the films
- Post-fabrication analytics: emission spectroscopy, lifetime, and QE measurements of the LCS down-conversion films
- Post-fabrication analytics: measuring PCF of the down-conversion polymer nanocomposite LSCs
- Post-fabrication analytics: electro-, thermo-conductivity, Seebeck coeff, and *ZT* of AZO-PMMA nanocomposite TE films
- Reporting, publications, training

Processing instrumentation (equipment)

- Pellet press
- New 3-beam PLD chamber
- New Nd:YAG laser PRO-250-50
- Nd:YAG laser Lab-170
- OPO with wavelength extender
- Femtosecond laser

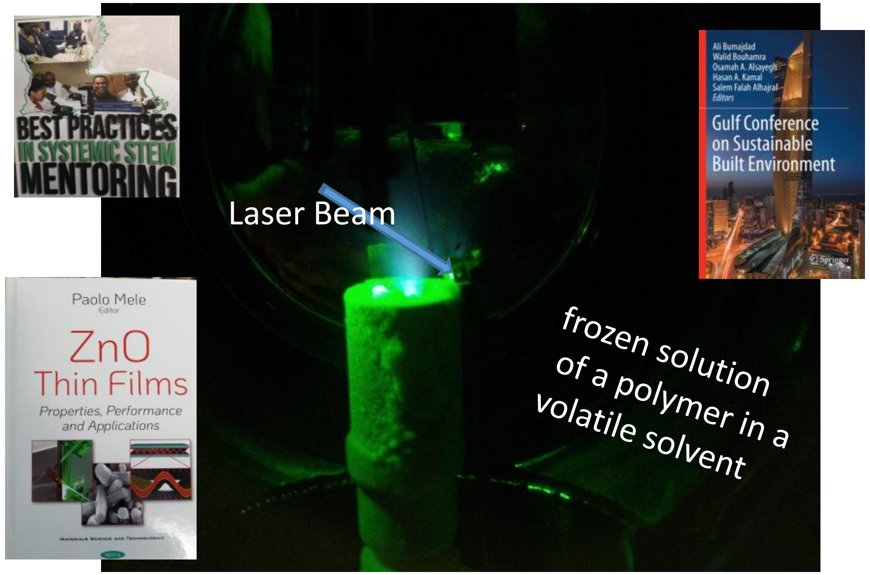
14

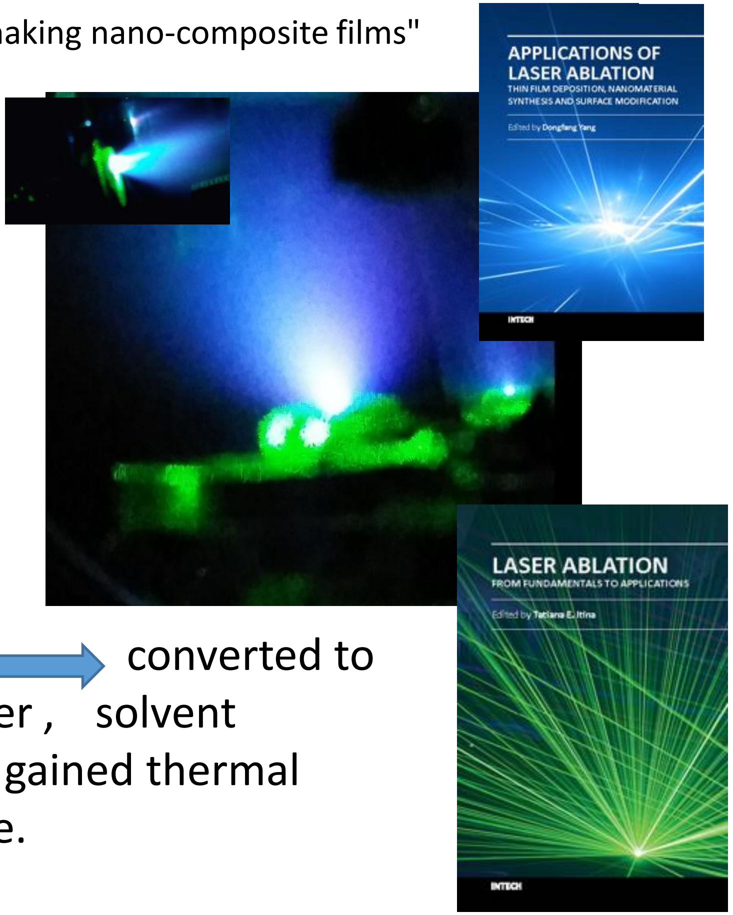


15 Matrix Assissted Pulsed Laser Evaporation D/ T concurrent PLD

"**Darwish's Textbbooks chapters**

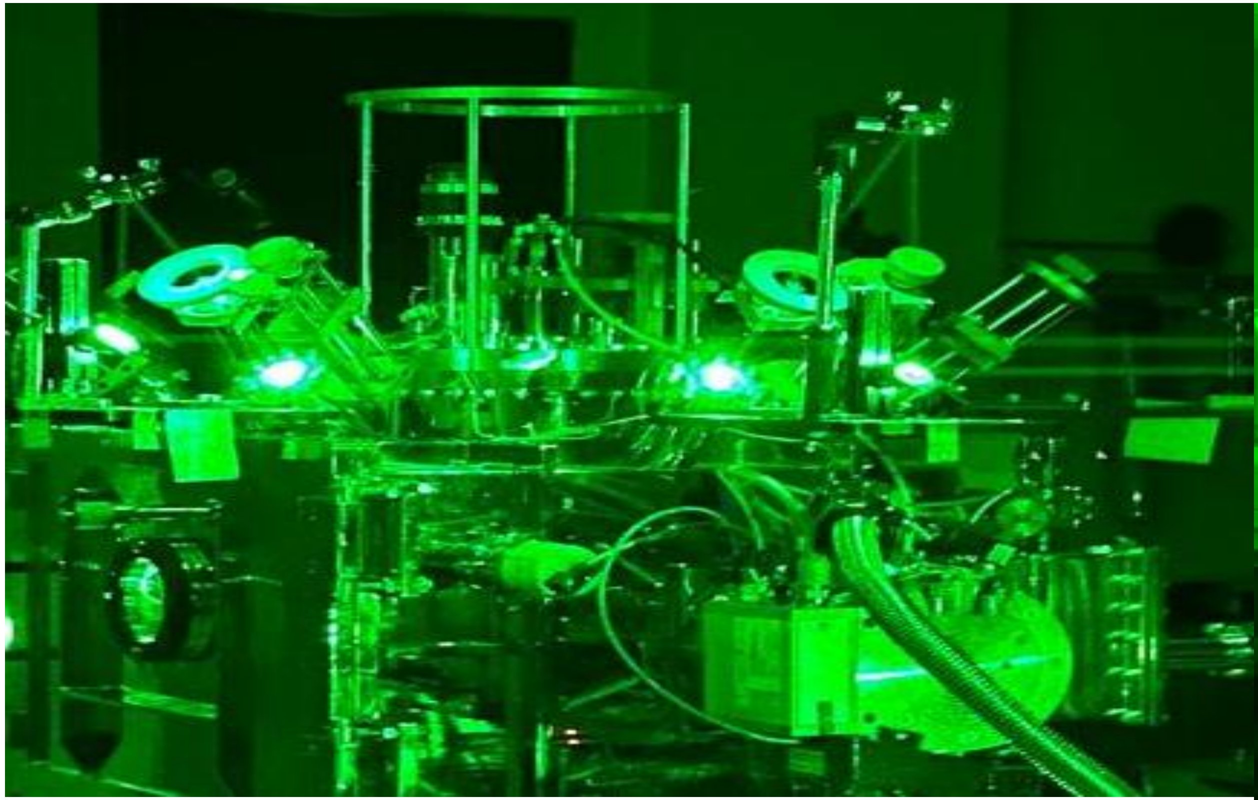
"Concurrent multi-target laser ablation for making nano-composite films"

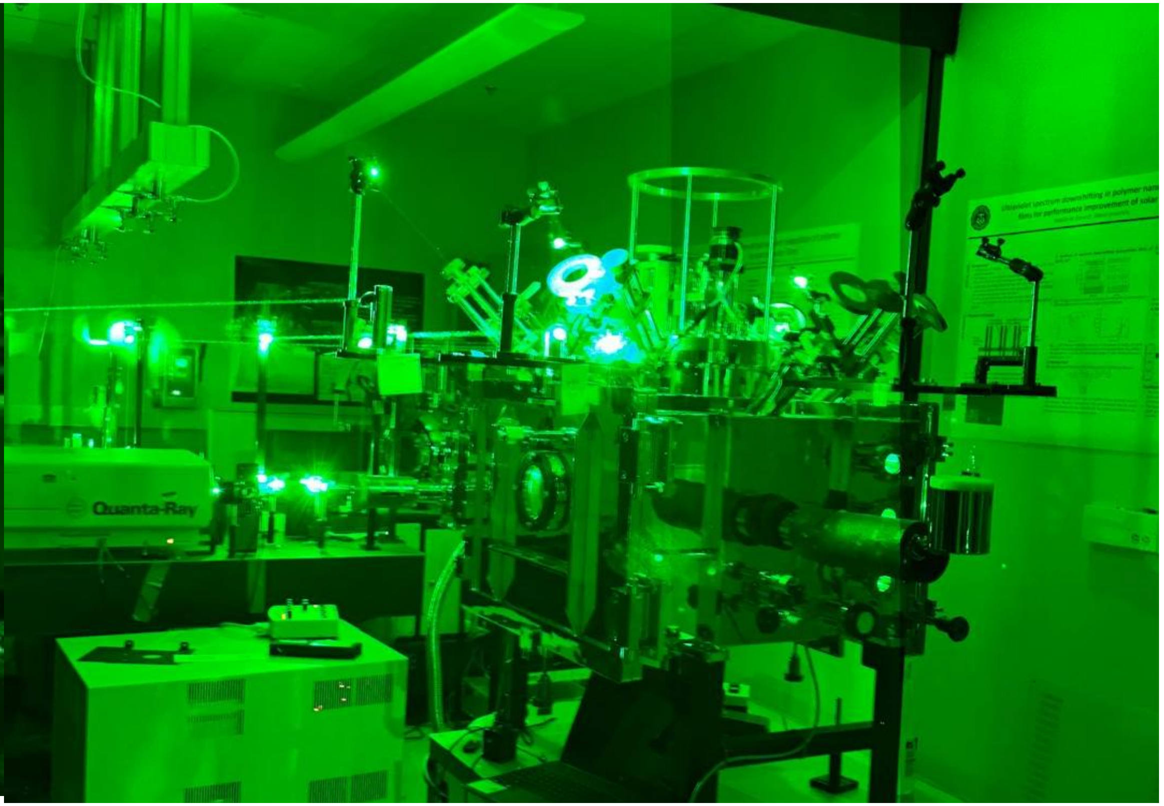




photon energy → solvent → converted to
thermal energy → heated polymer , solvent
vaporized, and polymer molecules gained thermal
energy and transferred to gas phase.

- 16 Six targets six laser beams concurrent PLD and MAPLE chamber





[(92) White House Summit: Developing a Bold Decadal Vision for Commercial Fusion Energy - YouTube]

Dr. Kim Budil
Director of Lawrence Livermore Laboratory

Dr. Kathy McCarthy
Associate Laboratory Director for Fusion and Fission Energy and Science, Oak Ridge National Laboratory

Dr. Abdalla Darwish
Presidential Professor at Dillard University Director of the Dillard University Physics LAMS Center

Dr. Anne White
Chair of the Department of Nuclear Science and Engineering at MIT

Dr. Steven Cowley
Director, Princeton Plasma Physics Laboratory

Dr. Mark Berry
Vice President, Research and Development at Southern Company

DAF AFOSR Success story and Impact of funding on Dillard University- Physics department

Return of investments:

1. Through DU SFS WISHES increased the awarence of minority women to the need of more well trained and qualified females on STEM fields to fill the DAF taskforce.

2. Published over 30 papers, 9 patents applications, 3 patens awarded. And 4 book chapters.

3. DU Physics is #1 in graduating Black females in physics in the country (NASEM, Forbes magazine,).

3.The patents changed the way the nanocomposite thin film is made around the world research labs with concurrent six laser beams ablating six targets to form a a homogenous mixed six plumes to form a new materials to push the envelope and functionality of it.

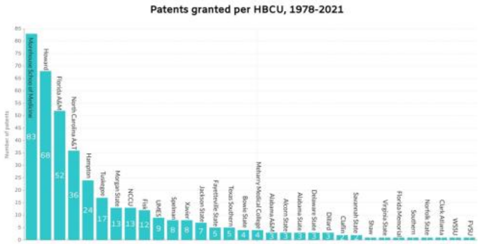
Center of Laser Ablation and Materials Science , DU Phy

1. **Professor Darwish was selected by the Whitehouse to represent all HBCU on the Fusion Summit in 2022.**

White House Summit: Developing a Bold Decadal Vision for Commercial Fusion Energy –Department of Energy

2. **MOU with SIT, Tokyo, Japan to exchange faculty and students. First to use the new Chamber at DU.**

1. **National and International collaboration Dr. Derek Passarelli, Principal Deputy Under Secretary for Science & Innovation DOE visiting DU LAMS center to observe the operation of the New chamber**



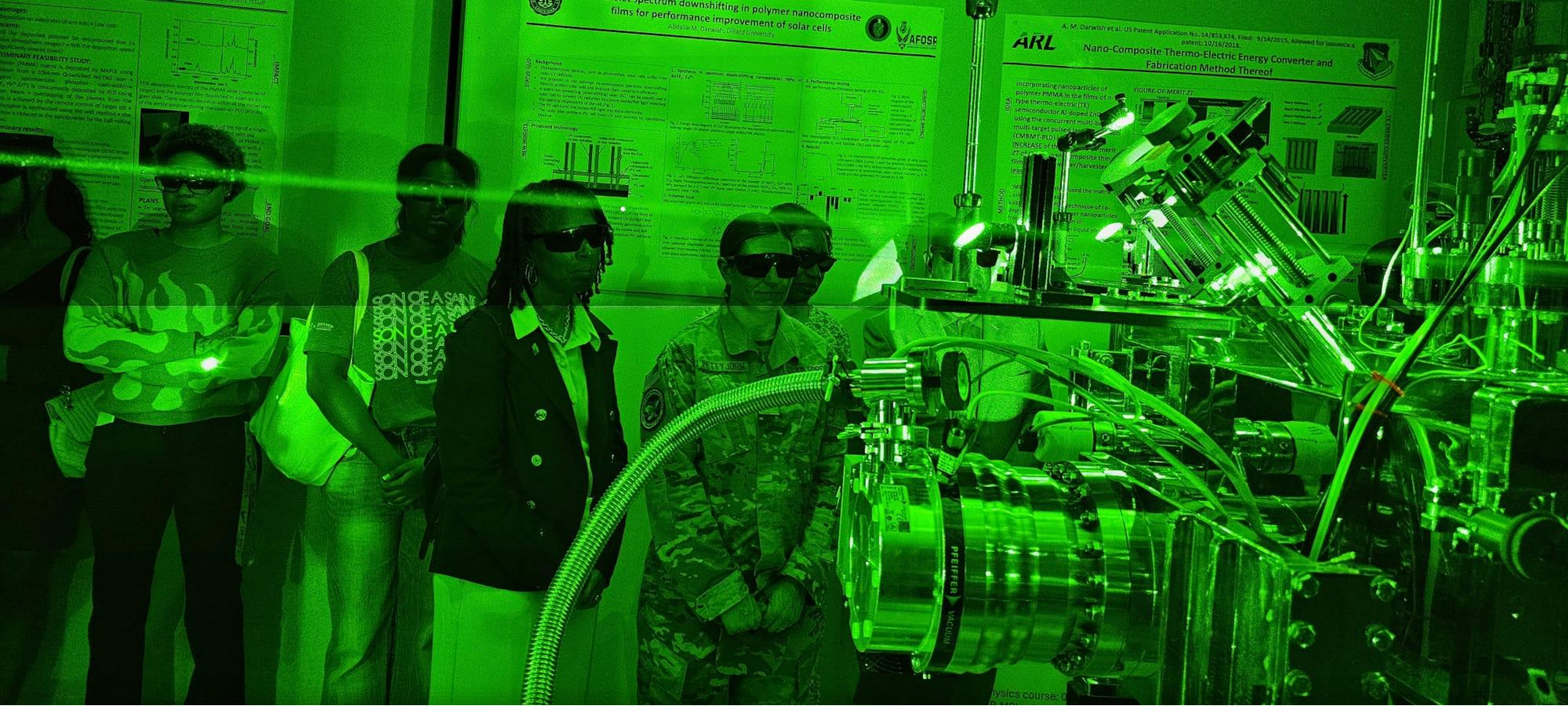
Source - US Patent and Trade Office Patent Database

The Plug

2. **DU Physics holds the position of #14 on # of patents among all the 114 HBCU**

Imapct on the University and physics department

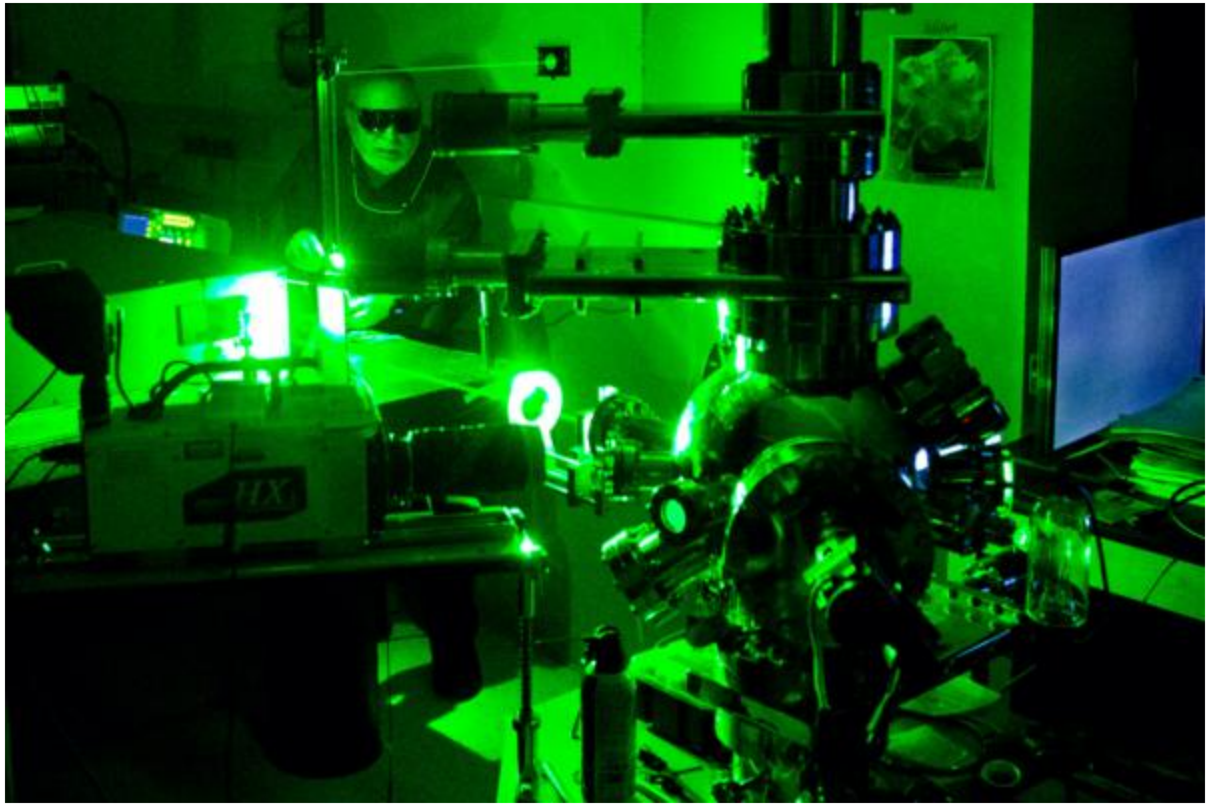
1. **With the support of the AFOSR, The physics department is able to carry out the research to advance the knowledge of basic research .**
2. **Thanks to the support from AFOSR Howard Slosberg, Charles Lee, Ken caster, Michael Yakes Kim Jacoby, Ed Lee and Ms. Evelyn Kent undersecretary of defense, HBCU Army for their support which is continuing to pay off everyday and lead to a great success story ,**
3. **Now, DU physics dep is part of the Semiconductor Research Corporation SRC CHIPS USA Institute .**



Honorable Assistant secretary of Defense Dr. Aprille Ericson visiting LAMS center during her site visit July 2024

Honorable Assistant secretary of Defense Dr. Aprille Ericson visiting DU Physics LAMS center during her site visit July

https://www.bing.com/videos/riverview/relatedvideo?q=Dr.+Abdalla+Darwish+preisedintial+Professor+Dillard+University&&view=riverview&mmscn=mtsc&mid=C987ECD95E3625ACEDC7C987ECD95E3625ACEDC7&&aps=12&FORM=VMSOVR



https://www.forbes.com/sites/marybethgasman/2021/07/19/the-talent-and-diversity-of-hbcu-faculty/?sh=33e353744d90

DU physics second top producer of African American Females in physics in the country