AFRL

HIGH-ENERGY RADIATION-MATTER SYSTEMS

JOEL N. BIXLER

Air Force office of Scientific Research

24 Feb 2026

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AIR FORCE RESEARCH LABORATORY

AF Office of Scientific Research (AFOSR)
- Aerospace, Chemical, & Material Sciences
- Physics & Electronics
- Mathematics, Information, & Life Sciences
- Education & Outreach

Aerospace Systems (RQ)
- Air Vehicles
- Control, Power, & Thermal Management
- High Speed Systems
- Space & Missile Propulsion
- Turbine Engines

Directed Energy (RD)
- Directed Energy & EO for Space Superiority
- High Power Electromagnetics
- Laser Systems
- Weapons Modeling & Simulation

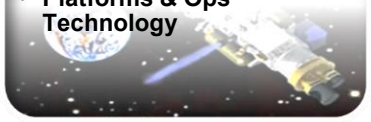
Information (RI)
- Autonomy, C2, & Decision Support
- Connectivity & Dissemination
- Cyber Science & Technology
- Processing & Exploitation

Human Systems (RH)
- Bio-Effects
- Decision-Making
- Human-Centered ISR
- Training

Munitions (RW)
- Ordnance Sciences
- Fuze Technology
- Munitions AGN&C
- Terminal Seeker Sciences
- Munitions System Effects Science

Sensors (RY)
- Advanced Devices & Components
- Layered Sensing Exploitation
- Advanced Sensing (RF/EO)
- Spectrum Warfare

Space Vehicles (RV)
- Space Electronics
- Space Environmental Impacts & Mitigation
- Space EO/IR
- Space Experiments
- Platforms & Ops Technology



Materials and Manufacturing (RX)
- Functional Materials & Applications
- Manufacturing & Industrial Technology
- Structural Materials & Applications
- Support for Operations

- AFRL's **mission** is to *lead, discover, develop and deliver science, technology and innovation for Warfighters.*
- AFRL supports the Science & Technology needs of two services: the **Air Force** and the **Space Force.**
- **Workforce: ~11,200** employees Military, Government civilians, and Contract positions
- **Locations** in **10** States California, Florida, Hawaii, Nevada, New Mexico, New York, Ohio, Tennessee, Texas and Virginia
- International Sites in **5** Countries United Kingdom, Japan, Brazil, Chile and Australia

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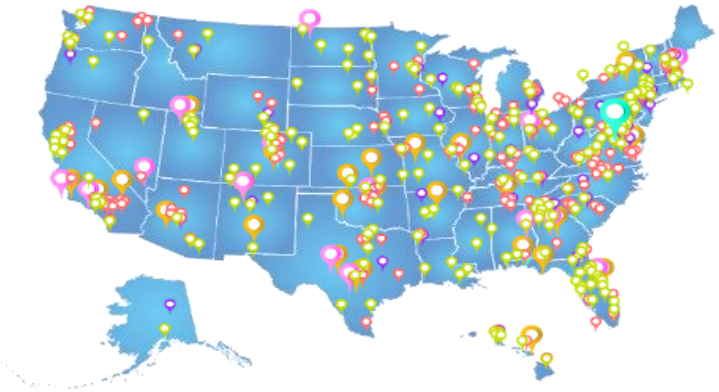
AFOSR's Mission is to Discover, Shape, Champion, and Transition High Risk Basic Research to profoundly impact the future Air and Space Forces

We build bridges to the world's most prestigious universities and talented researchers to enhance partnerships and provide revolutionary science and technology discoveries to the Warfighter.

DAF Link to Academia

Global Footprint and Reach

STEM Outreach Impact



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Who We Are

A small organization with a big mission …

to Discover, Shape, Champion and Transition High Risk Basic Research to profoundly impact the future Air and Space Force

Scientists & Engineers and Business Professionals

- Active-duty Air & Space Force
- All-service veterans
- Renowned academics
- Passionate civil servants

A global network of talent

We partner, grow and discover with a global network of the greatest scientific minds in the world, pulling them into our ecosystem, launching career trajectories, and strengthening their contributions to national defense.

We are the Basic Research Arm of the Department of the Air Force and AFRL

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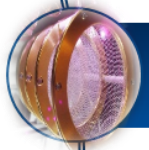
What We Do

AFRL/AFOSR sets and leads entirely new research directions pushing the bounds of conventional knowledge

AFRL/AFOSR provides awareness, engagements, and relationships to global basic research



AFRL/AFOSR aligns its research strategy to current and future Air and Space Force needs

AFRL/AFOSR takes “smart” risks in emerging areas of cutting-edge science

AFRL/AFOSR strengthens and shapes science and technology (S&T) human talent pathways – the next generation of scientists and engineers

AFRL/AFOSR forges and deepens external domestic and international partnerships to discover bold, pioneering science and accelerate research transition opportunities

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How We Work

FIND

30+ Program Officers (POs), **20+** International Program Officers (IPOs) and **7** Program Managers (PMs) reaching scientists & engineers globally

FORM

Shape emerging science into high-performing teams and portfolios that address long-term basic science barriers to future DAF capabilities

FUND

1,600+ extramural research grants at **180+** US universities in **40+** states

200+ intramural research grants at AFRL Technical Directorates (TDs) & Air Force Institute of Technology

340+ international grants in **40+** countries on **6** continents

FORWARD

Transition through other AFRL Technical Directorates (TDs), Small Business Innovation Research & Small Business Technology Transfer (SBIR/STTR)

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Science & Engineering Division (RT)

AFRL

RTA		RTB		RTC	
Engineering & Complex Systems	**Information & Networks**	**Physical Sciences**	**Chemistry & Biological Sciences**	**Education & Outreach**	**OSD Programs**
Energetic Solid-State Physics & Mechanochemistry	Computational Cognition & Machine Intelligence	Aerospace Materials for Extreme Environments	Biophysics	Science &Technology Fellowships	Multidisciplinary University Research *
GHz-THz Electronics	Computational Math	Atomic & Molecular Physics	Human Performance & Biosystems	Summer Faculty Fellowship Program	Defense University Research Instrumentation *
Energy, Combustion & Thermodynamics	Dynamical Systems & Control Theory	Electromagnetics	Molecular Dynamics & Theoretical Chemistry	AFRL Scholars	National Defense S&E Graduate Fellowships *
High-Speed Aero	Info Assurance & Cybersecurity	Optoelectronics & Photonics	Natural Materials & Systems	AF Institute of Technology Partnership	Minerva Research Initiative *
Aerospace Composite Materials	Science of Info, Computation, Learning & Fusion	High Energy Radiation-Matter Systems	Organic Materials Chemistry	USAF Academy AF Institute of Technology Partnership	Awards to Stimulate & Support Undergraduate Research *
Propulsion & Power	Trust & Influence	Quantum Info Sciences	Mechanics of Multifunctional Materials & Microsystems	DAF K-12 STEM / LEGACY	Presidential Early Career Awards *
Agile Science of Test & Evaluation	Complex Networks	Space Physics	Space Biosciences	Young Investigator Program	
Multi-Scale Structural Mechanics & Prognosis	Mathematical Optimization	Astrodynamics		Historically Black Colleges & Universities / Minority-Serving Institutions	OSD HBCU/MSI
Aerodynamic Sciences	Cognitive & Computational Neuroscience	Physics of Sensing		Government-University-Industry Research Roundtable	Defense Established Pgm to Stimulate Competitive Research
	Dynamic Data & Info Processing	Condensed Matter Physics		National Science Portal	
		Ultrashort Pulse Laser- Matter Interactions		Small Business Innovation Research/Tech Transfer	*Devolved Programs

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AFRL/AFOSR International Basic Science Portfolios

TRL 9
- Actual system "flight proven" through successful mission operations

TRL 8
- Actual system completed and "flight qualified" through test and demonstration

TRL 7
- System prototype demonstration in an operational environment

TRL 6
- System/subsystem model or prototype demonstration in a relevant environment

TRL 5
- Component and/or breadboard validation in relevant environment

TRL 4
- Component and/or breadboard validation in a laboratory environment

TRL 3
- Analytical & experimental critical function and/or characteristic proof-of-concept

TRL 2
- Technology concept and/or application formulated

TRL 1
- Basic principles observed and reported

AOARD

- Aerospace Sciences
- Applied Math & AI
- Hypersonic Modeling & GNC
- Quantum Sciences
- Computer Sciences
- Digital Strat for A/C & Robotics
- Biophysics, Trust, Math
- Materials Chem & Nanoscience
- Sensors & Device Physics
- Advanced Manufacturing
- Physics & Space Science

EOARD

- Electricity & Magnetism
- Space Sciences
- Structures & Materials
- Aeronautical Sciences
- Physics and Space Science
- Directed Energy
- Life Sciences
- Sensors and Microelectronics

SOARD

- Aeronautical Sciences
- Space Sciences
- Physics & Microelectronics

How We Accomplish Our Mission

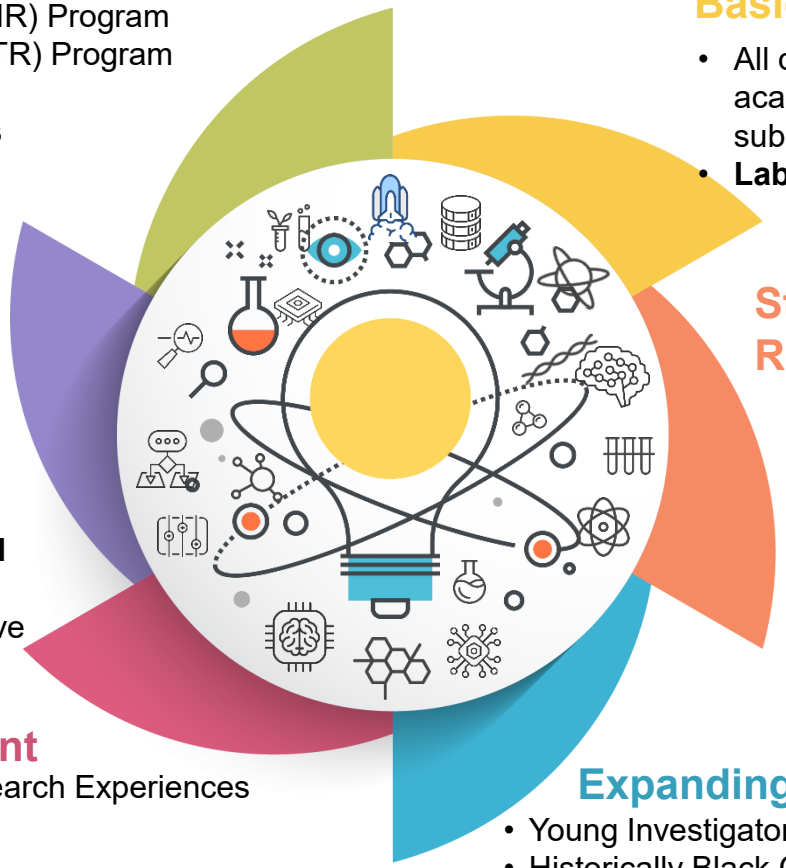
Bold=direct partnership with other TDs, DAF

Technology Transition

- Small Business Innovation Research (SBIR) Program
- Small Business Technology Transfer (STTR) Program
- **AFRL Regional Networks**
- ***Into the Wild* Algorithms to Operations**
- Partnerships for Transition

Basic Research Traditional Grants

- All qualified, responsible organizational applicants from academia, the non-profit sector, and industry are eligible to submit research proposals.
- **Lab Task Program**



Strengthening Academic Research Capabilities (& Partnership Potential)

- Multidisciplinary University Research Initiative (MURI) Program
- Space University Research Initiatives (SURI)
- **Laboratory-University Research Initiative (LUCI)**
- Defense University Research Instrumentation Program (DURIP)
- **Presidential Early Career Award for Scientists and Engineers (PECASE)**
- Defense Established Program to Stimulate Competitive Research (DEPSCoR)
- **University Nanosat Program**

Strengthening Air & Space Force Research Capabilities

- **ProtoStar Program**
- **Star Team Awards**
- **University Centers of Excellence**
- **US Air Force Academy Program**
- **AFIT Program**
- **Summer Faculty Fellowship Program (SFFP)**
- **Science & Technology Fellowship Program (STFP)**

Workforce Pipeline Development

- Awards to Stimulate and Support Undergraduate Research Experiences (ASSURE; with NSF)
- **AFRL Scholars**
- **National Defense Science and Engineering Graduate Fellowship Program (NDSEG)**
- DAF Pre K-12 STEM/Legacy

Expanding Air & Space Force Academic Reach

- Young Investigator Program (YIP)
- Historically Black Colleges & Universities/Minority Serving Institutions (HBCU/MSI) Program
- **AFRL Basic Research National Science Portals (NSPs)**
- Government-University-Industry-Philanthropy Research Roundtable (GUIPRR)

Diverse Ecosystem of Programs to Maximize Discovery & Transition to AFRL

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AFRL/AFOSR Strategic Partnership Ecosystem

Department of Defense

Air Force Research Laboratory (AFRL)
Army Research Office (ARO)
Army Research Laboratory (ARL)
Defense Advanced Research Projects Agency (DARPA)
Naval Research Laboratory (NRL)
Office of Naval Research (ONR)
United States Marine Corps (USMC)
United States Space Force (USSF)
and more…

Academia

Pre K-12
Junior Reserve Officers' Training Corps (JROTC)
Community Colleges
Universities
Historically Black Colleges and Universities (HBCUs)
Minority-Serving Institutions (MSIs)
Tribal Colleges and Universities (TCUs)

Other Government Agencies & Industry

Department of Energy (DOE)
Los Alamos National Laboratory
National Aeronautics and Space Act (NASA)
National Institutes of Health (NIH)
National Oceanic and Atmospheric Administration (NOAA)
National Science Foundation (NSF)
Sandia National Laboratories
United States Department of Agriculture (USDA)
and more…

Teaming of diverse areas is vital to next generation technology advancements.

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High Energy Radiation-Matter Systems

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High Energy Radiation-Matter Systems (HERMeS)

HERMeS is focused on the **controlling** the nonlinear/multi-scale/multi-physics phenomena that occurs at high energy density. This allows the **production of useful work** in the electromagnetic spectrum for a variety of missions:

- Directed Energy Attack/Counter-DE Defense
- Electronic Warfare
- Radar, LIDAR, Remote Sensing
- Communications
- Radiation Damage Simulators
- EM/Biophysics Safety

Image from Wikipedia

High-Energy/Power Lasers

- Production of coherent "short-wavelength" high power laser light with good beam quality and high efficiency
- Typically quantum physics

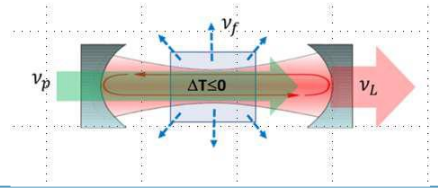

Image from Sheik-Bahea

Laser/RF-Matter Interaction

- Fundamental EM-matter interaction
- Critical for high-power/energy optics and beam propagation

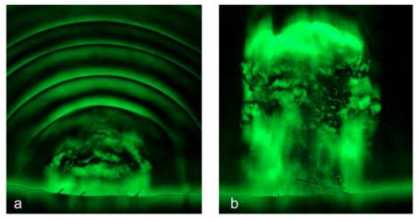

Image from Vogel

High-Power EM (HPEM)

- Production of coherent "long-wavelength" high-power electromagnetic signals
- Typically classical physics

Image from Wikipedia

Non-equilibrium Thermodynamics

- Track the flow of energy, charge, and information through a system
- Coupling of light with neutral and charged matter

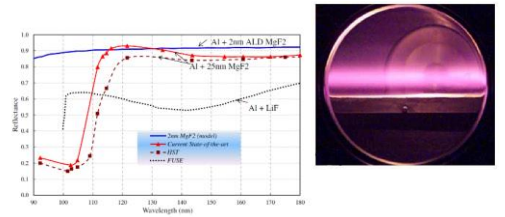

Image from Walton

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General Directed Energy (DE) Research Categories at AFRL

1. Lasers
2. High Power Microwaves (HPM)
3. Charged Particle Beams

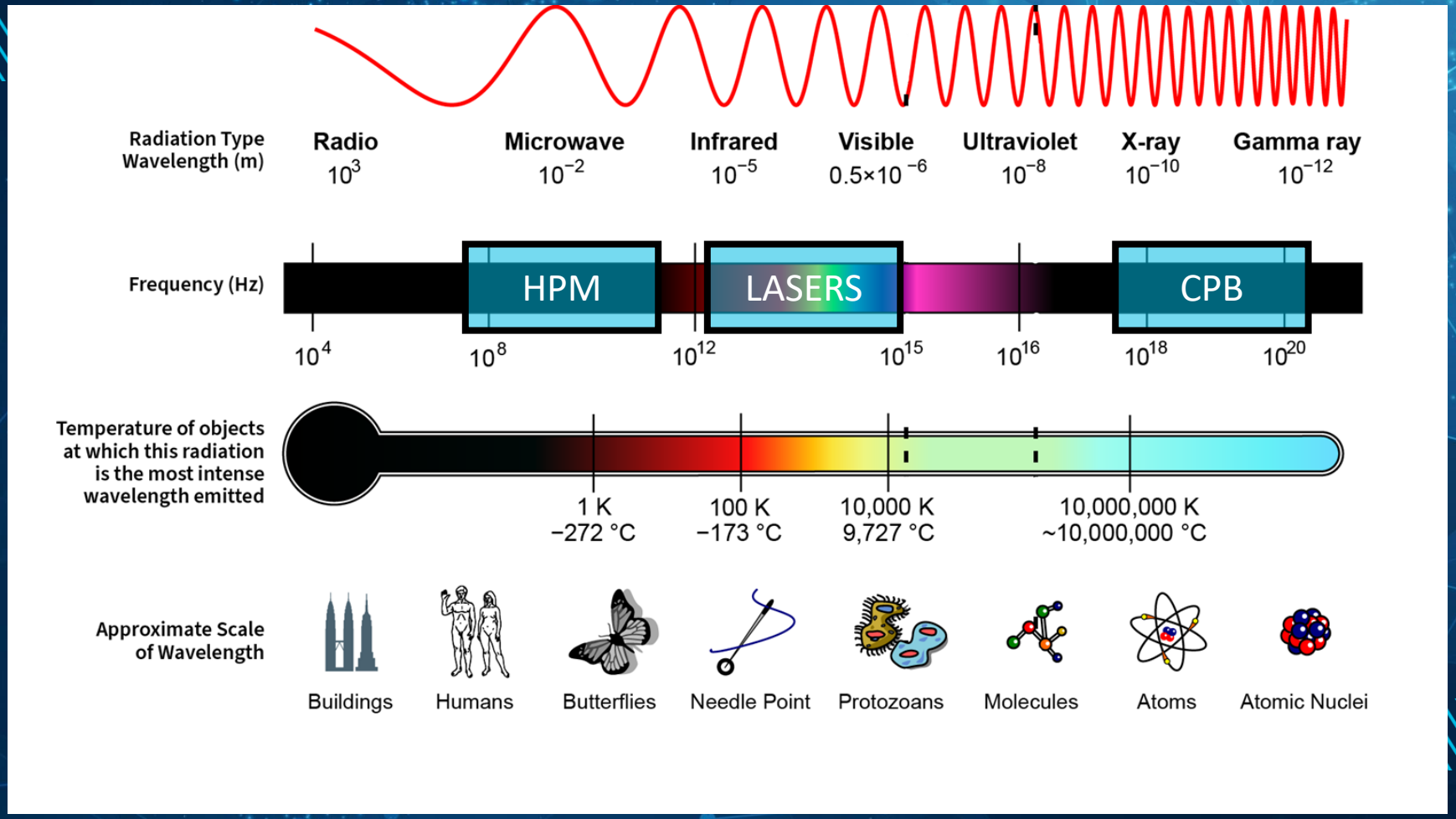

Image From: The Electromagnetic Spectrum. ***Authored by****: OpenStax College.* *https://openstax.org/books/university-physics-volume-2/pages/16-5-the-electromagnetic-spectrum.*

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High-Energy/Power Lasers

Novel Optical Fiber Theory

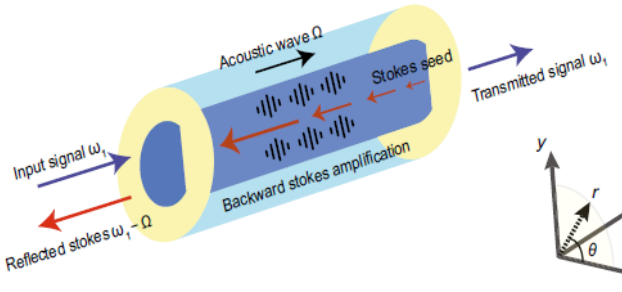


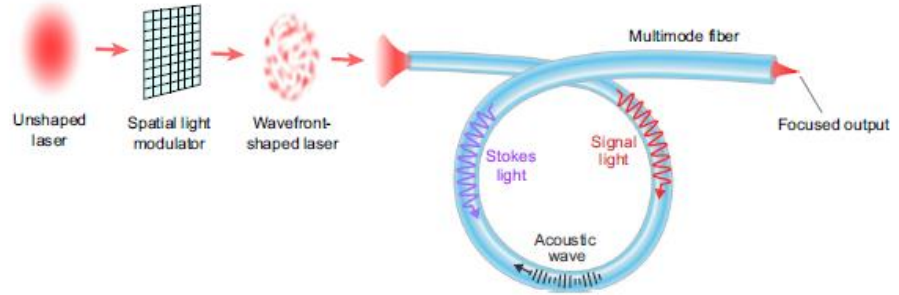
FIG. 1. Schematic of SBS in a multimode fiber with arbitrary core shape (here, D-shaped). Stokes-shifted backward-travel light (seeded by spontaneous Brillouin scattering) experiences amplification due to the scattering of the forward-going signal by acoustic phonons, which are generated by electrostriction. This process can take away significant power from the signal and limits the transmitted power.

PHYSICAL REVIEW X **14,** 031053 (2024)

Theory of Stimulated Brillouin Scattering in Fibers for Highly Multimode Excitations

Kabish Wisal,[1] Stephen C. Warren-Smith,[2] Chun-Wei Chen,[3] Hui Cao,[3] and A. Douglas Stone[3,*]
[1]*Department of Physics, Yale University, New Haven, Connecticut 06520, USA*
[2]*Future Industries Institute, University of South Australia, Mawson Lakes, South Australia 5095, Australia*
[3]*Department of Applied Physics, Yale University, New Haven, Connecticut 06520, USA*

High Energy Fiber Amplifiers for DE Applications

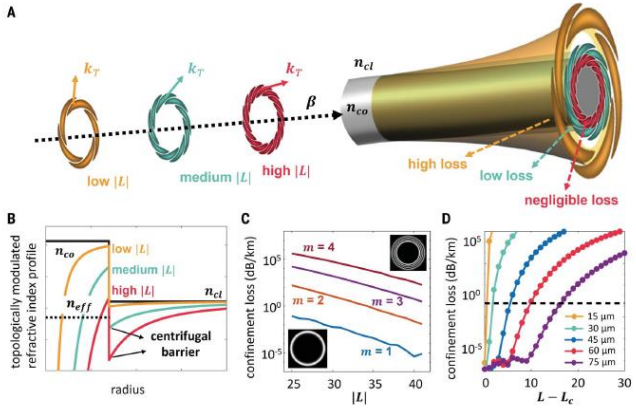


Nature Communications (2023)14:7343

FA9550-20-1-0129
FA9550-20-1-0160

Mitigating stimulated Brillouin Scattering in fiber amplifiers

Multi-Mode for Communication for Space



Science 380, 278–282 (2023)

FA9550-14-1-0165

Scaling information pathways in optical fibers enabling advanced quantum computer networks

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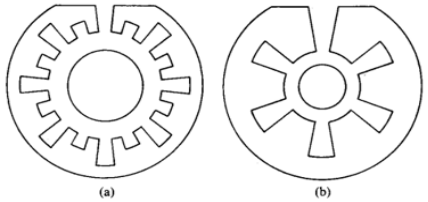
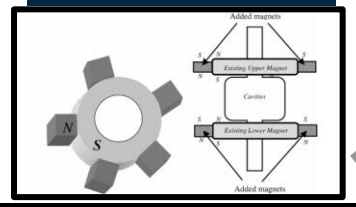
AFOSR-funded Relativistic Magnetron Evolution

NC State



Rising sun A6

University Michigan



Cathode Development: Priming

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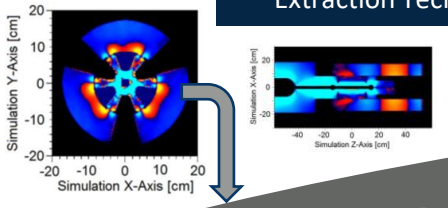
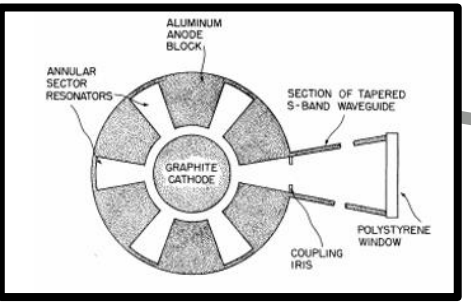
All Cavity-Magnetron Axial Extraction Technique



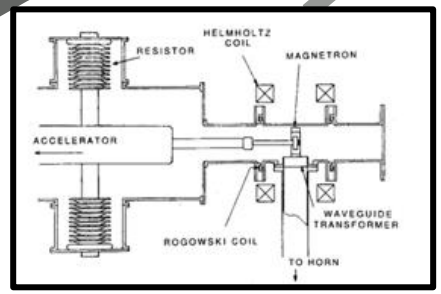
Tactical HPM Operational Responder (THOR)

1980 1990 2000 2005 2012 2019

MIT

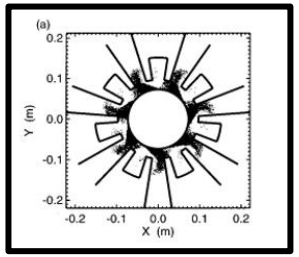


Development of the A6 Anode Bekefi and Palevsky



Temporal and Spectral Analysis of A6 Treadu/Doggett

Sandia/AFRL



First PIC and Efficiency Analysis of A6 Lemke/Genoni/Spencer

University of NM

Fuks 2006
Mode Conversion in a Magnetron With Axial Extraction of Radiation

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Questions?

plasma@us.af.mil

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