Expanding the Fusion Technology Ecosystem: DIII-D as a Small Business Incubator

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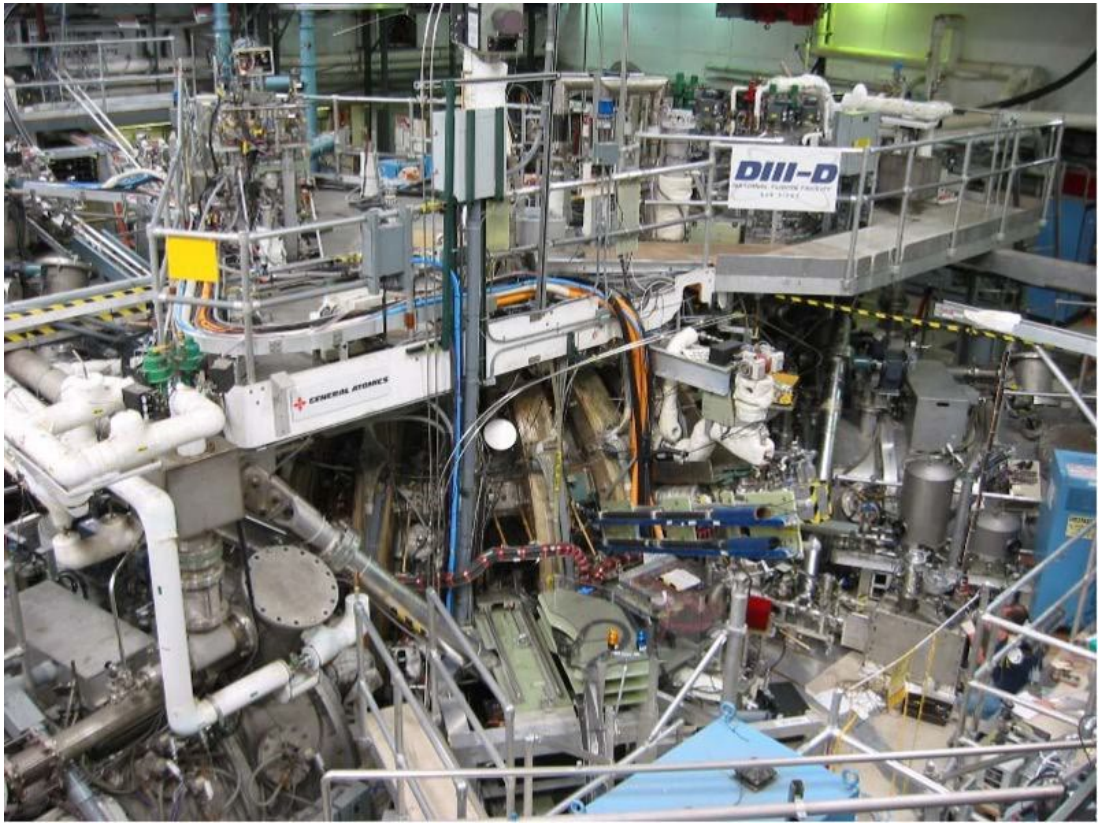
PALOMAR
SCIENTIFIC INSTRUMENTS



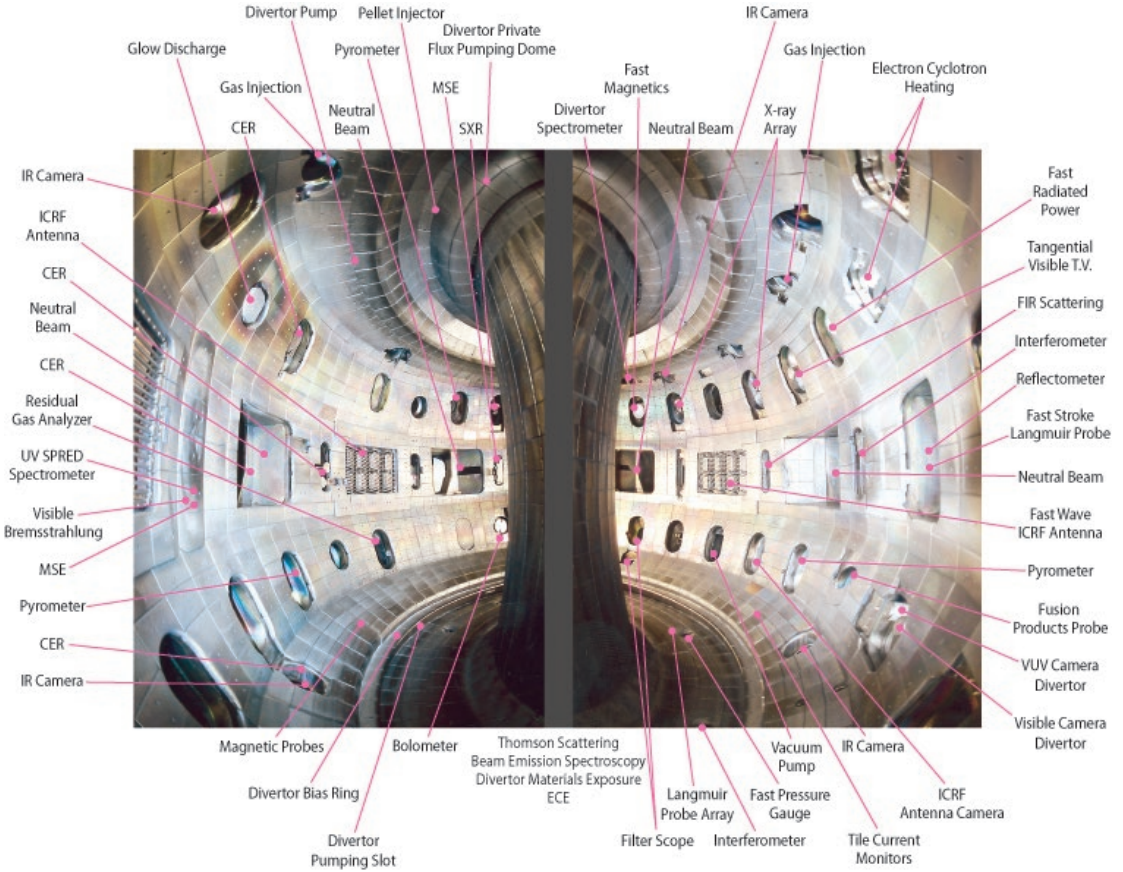
About PSI

- **PSI Founded by Dr. Daniel F. Finkenthal**
  - Professor of Physics and Engineering-Palomar College
  - Graduated UC-Berkeley 1995; Thesis work done on DIII-D
- **Established to provide engineering solutions to DIII-D and workforce development opportunities**
  - DIII-D provides a unique environment for developing and testing electronics for the fusion energy ecosystem
  - Academic environment alongside world wide experts ideal for training and learning
- **PSI has leveraged its access to D3D to scale up, including an active internship program**
  - Experts in Electrical Engineering for Fusion Diagnostics
  - Specialists in real-time DSP with FPGA technologies
- **PSI Provides Fusion Workforce Development**
  - Regular internships with CSUSM, SDSU, UCSD, and UCI
  - Local BS engineering grads have been mentored and matriculated
- **Fully equipped design and prototyping center**
  - 3,000 square foot Facility in San Marcos, CA
  - ISO-certified test equipment
- **Primary obligation is now to ITER to TIP System**
  - Toroidal Interferometer-Polarimeter responsible for line integrated density essential for plasma control
  - Currently in Final Design Phase

Visiting ITER to review design interfaces

“Necessity is the Mother of Invention” --Plato

- **DIII-D Leads in Diagnostic Development**
  - I have lost count!
- **Diagnostics have needs**
  - Both routine and exotic electronics are required
- **Solving problems provides opportunities**
  - Matching problems to people who thrive on solving problems
- **DIII-D provides prototyping and testing environment for fusion technologies**
  - Mutual and shared benefits; physics gets solutions and electronics gets tested
- **DIII-D provides access to exceptional technologies and environmental conditions**
  - Ionizing Radiation- *including* **<u>neutrons</u>**
  - Heterodyned Lasers
  - Mid and Far Infrared Lasers
  - Microwave reflectometers and emissions
  - Neutral beams
  - *and more…*



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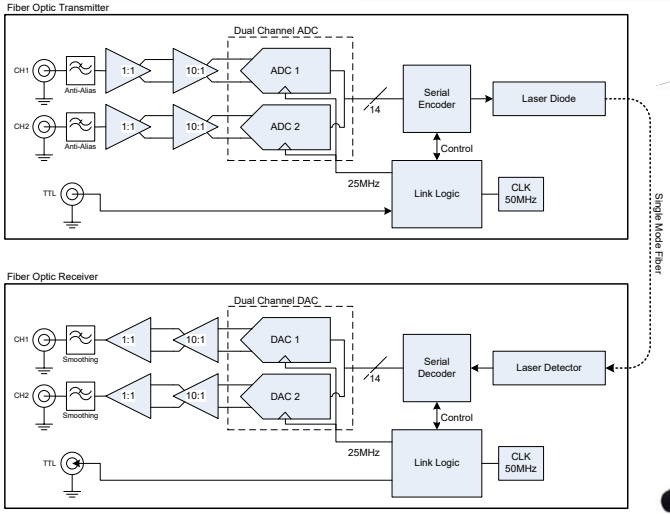
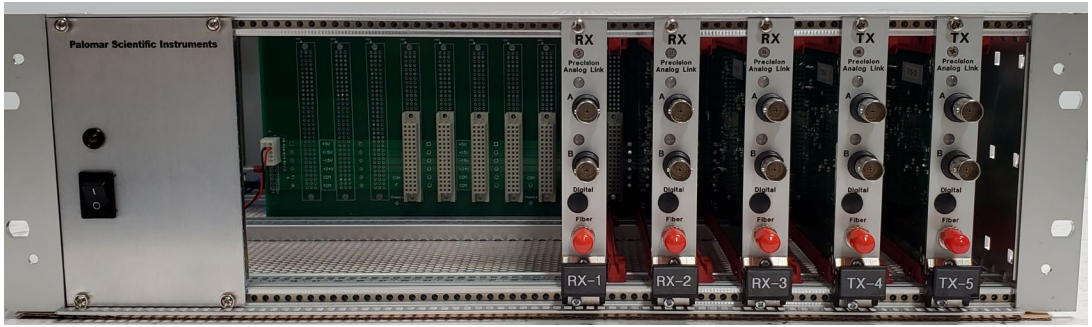
Precision Fiber Optical Link (AFL)

- **Transmits Two analog signals over fiber**
  - High precision ADC/DAC technology provides 25MHz Bandwidth each channel using digital transmission technique
  - Resistant to EMI and Ionizing Radiation
  - Provides Isolation in Harsh Environments
- **Developed for Gyrotron Control**
  - 2005 Problem: Analog feedback control signals needed to be passed between control system and high-voltage "Hot Deck".
  - Existing COTS suffered drifts, limited bandwidth
- **Successful commercial product**
  - Deployed at 6 fusion facilities and labs
  - Recently adapted to biomedical research and geological exploration





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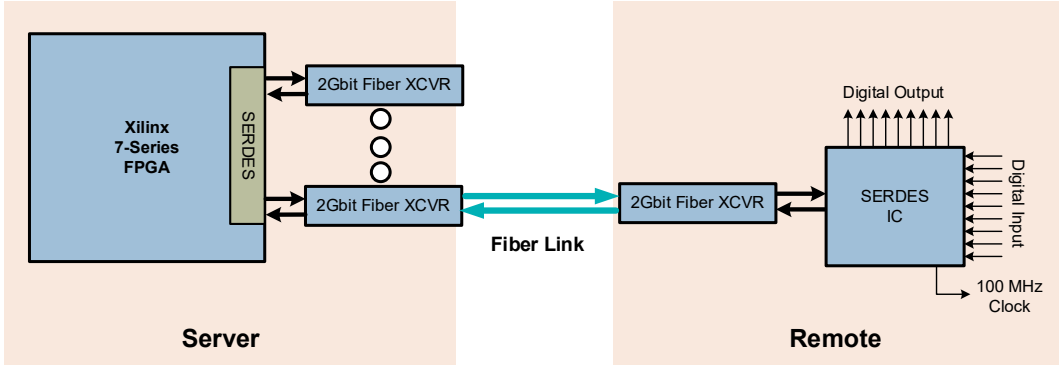
AFL evolved into Rad-Resistant Remote DAQ System

- **Extensive testing of AFL on DIII-D proved technology**
  - Dozens of links in service for over 15 years
- **AFL became the basis of a remote data acquisition (DAQ) system**
  - Now used on Langmuir Probe System (Sandia National Labs)
  - Remote modules in pit provide Analog Input and Analog Output
  - FPGA-based server in control room generates waveforms and acquires data
- **Generalized approach extends FPGA IO to hazardous environments**
  - Removes FPGA, computer, and other radiation sensitive electronics
  - Ideal for fusion plants
- **Now being tested on NIF**
  - May provide backend for a rad-hard imaging system/camera being developed



Top: Illustration of the method developed by PSI for extending the digital input/output of an FPGA to a remote location over fiber optics. Bottom: Remote Data Acquisition System being prepared for testing on NIF

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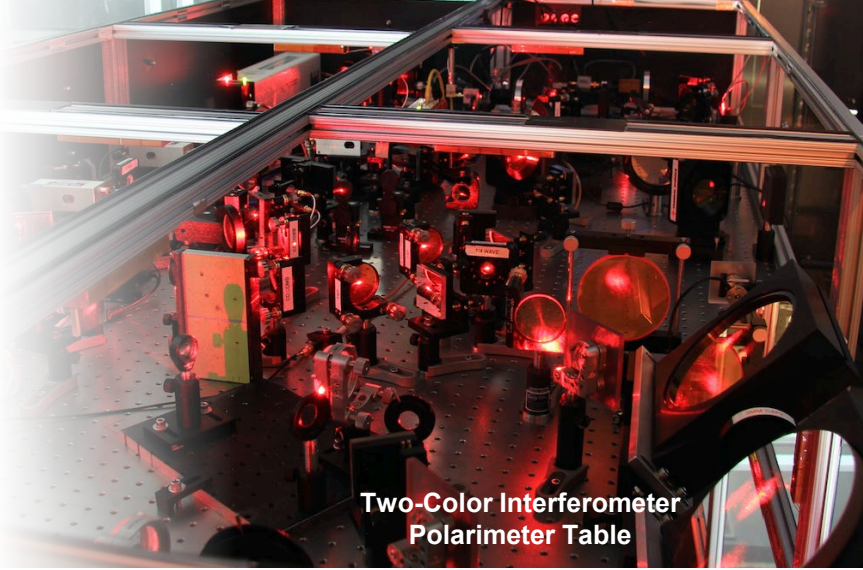
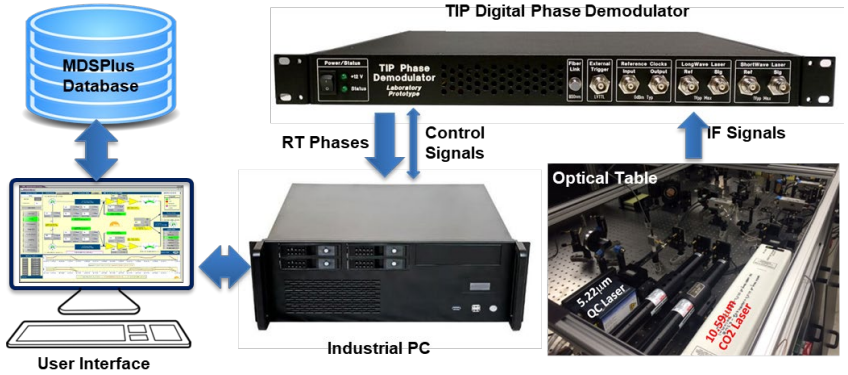
Improving Existing Diagnostics

- **Example: Two-color Interferometer**
  - Provides real-time line integrated density for plasma control
  - DIII-D utilizes CO2 and HeNe lasers
  - Heterodyne technique using Acousto-optical modulators to generate 40MHz IF Signals
  - Requires precise real-time phase measurement
  - Phase measurements must be scaled, added, and subtracted in real time
- **Old system on DIII-D relied on analog technique**
  - RF mixers and IQ demodulators
- **Y2008 Upgrade introduced DSP and FPGA technologies**
  - PSI became Pioneer in this application
  - Several phase demodulator/density computer systems sold
  - Developed FPGA-based Fusion Neutron Counter System
  - Now being applied to ITER TIP System





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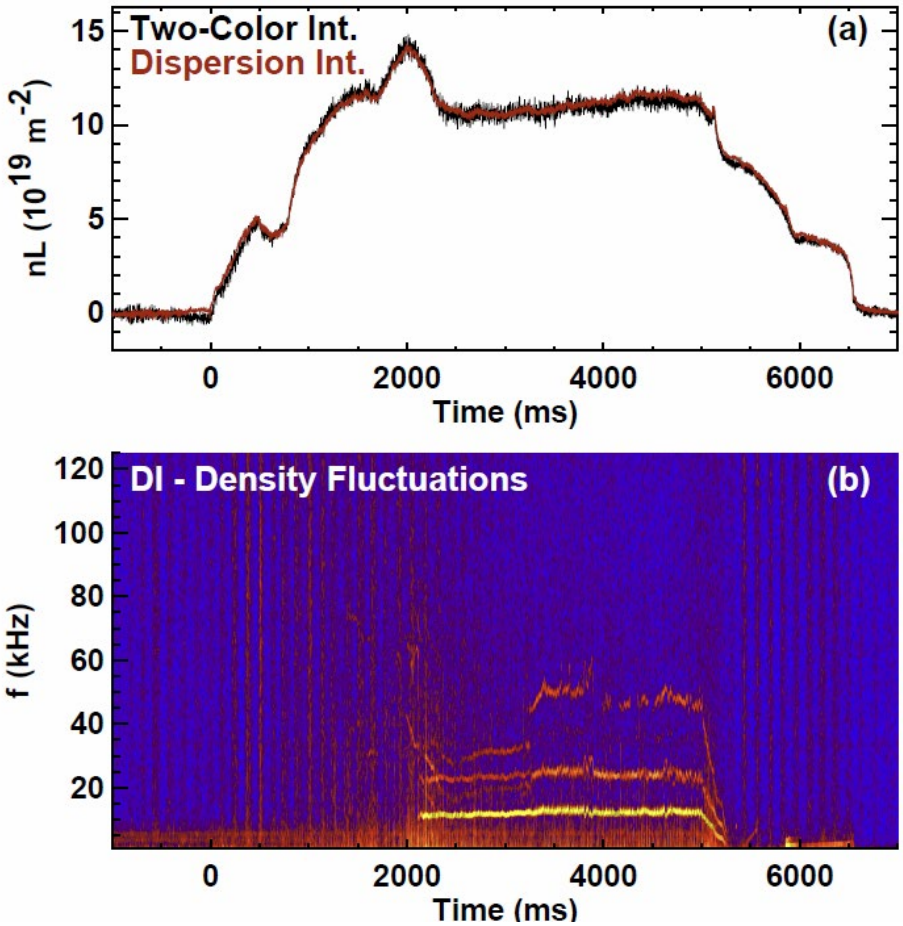
Digital Phase Demodulator has Extensive Applications

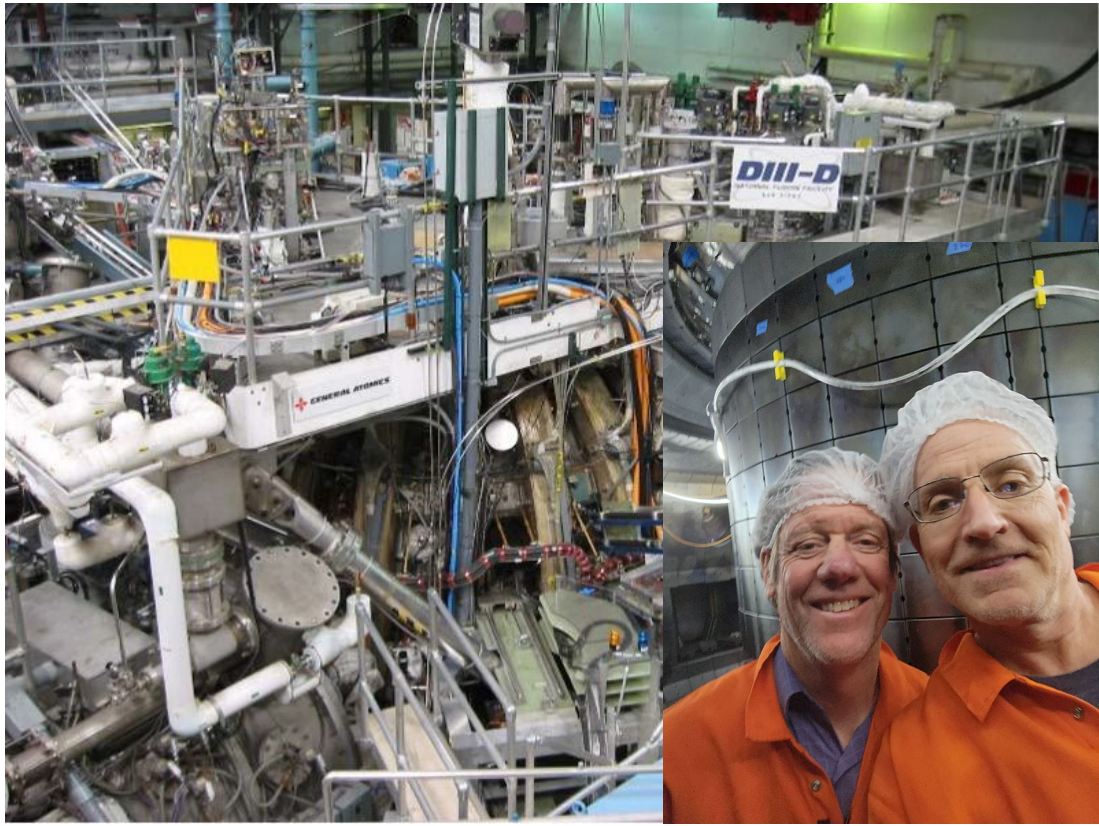
- **DIII-D Vibration Compensated CO2 Interferometer**
  - In operation since 2008 using Virtex-II generation FPGA
  - Critical Diagnostic
  - Real-Time Plasma Control
  - Unparalleled performance provides fluctuation measurement
  - Upgraded 2015 to Kintex-7 FPGA
- **Dispersion Interferometer (DI)**
  - Akiyama setup demonstration DI system on DIII-D in 2016
  - Uses single 40MHz Heterodyne Laser
  - TIP DPD used for Phase measurement
  - Results shown on right
- **DPD tested on ITER TIP Diagnostic (Tangential Interferometer-Polarimeter)**
  - Now baseline design



Summary

- DIII-D Provides Opportunities for Small Business Concerns
- DIII-D has dozens of systems that can be leveraged for testing and developing the technologies needed for the commercial fusion ecosystem
- DIII-D has many dedicated experts available with essential knowledge

Thank You!



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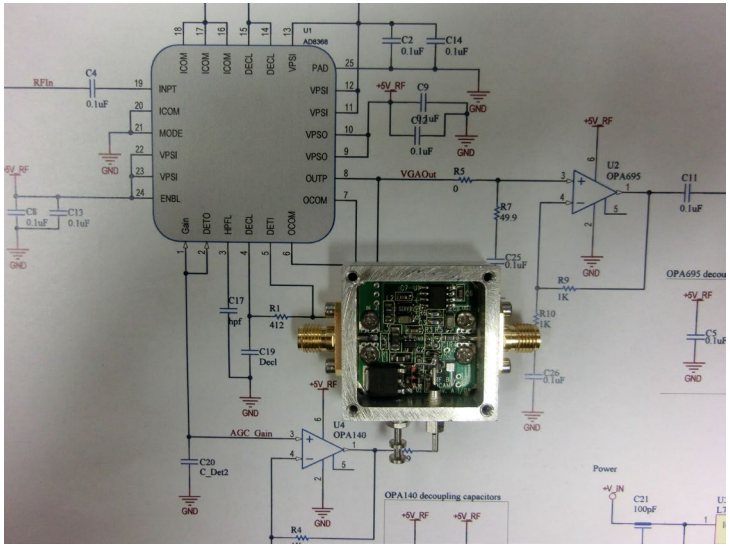
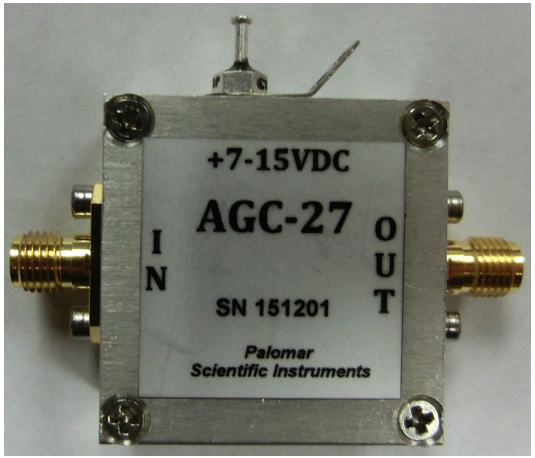
Backup slides





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