

The widest range of  
mission-critical interconnect  
technologies in the world

## High-Power >20 W Single-Mode Fibre Optic Connector for Directed Energy Weapon Systems

Dr Ron Logan, Glenair Inc., Glendale, California, USA  
Davinder Basuita, Glenair UK Limited, Mansfield, UK



**MISSION-CRITICAL**  
**INTERCONNECT**  
**SOLUTIONS**

EPIC Technology Meeting on Photonics in Defence  
Kielce, Poland  
6-7 Sept 2023



# Glenair Overview

An interconnect industry leader since 1956

- Products
  - Connectors, complex cable assemblies, backshells, conduit, braid, tooling, and fibre optics
- Primary markets
  - Aerospace, avionics, space, deep sea (oil / gas) and nuclear
- More than 2.5 million square feet factory space world-wide, 7000 employees
- Privately owned, not beholden to any stock markets



Glenair UK, Mansfield, Notts.



MISSION-CRITICAL  
**INTERCONNECT  
SOLUTIONS**

# Glenair Harsh Environment Fibre Optic Interconnect Solutions



MIL-DTL-38999 Series III type



Glenair High Density (GHD)



ARINC 801



83526 GFOCA



Series 80 Mighty Mouse



Mil 28840



Glenair GFR Series  
Front-Release



Mil PRF 64266 NGCON



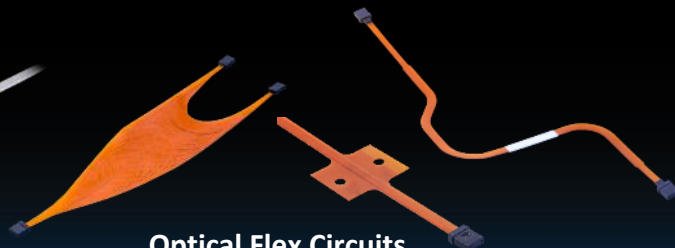
Eye-Beam GMA



SuperNine MT



Series 79 MT



Optical Flex Circuits

# Applications targeted for High-Power Single-Mode Fibre Optic Connectors

- Opto-Pyro detonation for launcher stage separation
- Free-Space-Optical (FSO) Links at 1064nm and 1550nm
  - High-rate optical FSO comms for air /sea / ground / space
  - 1W to 50W optical power
- High-resolution LIDAR systems
  - 1W to 50W, 1550nm / 1064nm or thereabouts
- Directed Energy Weapons at 1064nm
  - Multiple 20W-100W single-mode fibre laser modules are combined to create many kW output with maximum energy on target
- Standard and polarization-maintaining optical fibre



Directed energy weapon systems



LIDAR



Inter-satellite comms



Opto-pyro detonation

# Problem: High-Power Laser Deployment

- In many situations it's desirable to connectorise single mode high-power lasers or optical amplifiers for
  - Easing equipment build and integration
  - Plug-in / plug-out faulty units in the field
  - Transitioning these types of components into line replaceable units (LRUs)



Many high power laser / amplifier LRUs

# There are no ruggedised adequate single-mode high-power fibre optic connectors

- Above approx. 1W optical intensities can damage regular single mode physical contact (PC) connectors
  - Existing expanded-beam single-mode fibre optic connectors are lossy (1-2 dB)
  - Therefore, the current approach is to integrate systems using fusion splicing
    - Difficult to test subassemblies in production
    - Complicates the assembly process
    - Difficult to repair in the field
    - Doesn't support a line replaceable unit (LRU) strategy
- ⇒ Deploying and maintaining high-power laser / amplifier systems is problematic
- ⇒ Need better single-mode optical connectors

# What are the generic “wish-list” requirements for a directed energy weapon optical connector?

- Supports SMF & PMF, 10W - 100W CW power (Class 4)
  - Max < 0.5 dB (10%) loss fibre-to-fibre, ideally <0.25 dB ( 5%)
  - Ruggedized connector shells suitable for space / aero / ground / naval
  - Tactical environments: -40C to +85C, high shock / vibration, etc.
- Supports common wavelengths and fibre types
  - 1550nm and 1064nm
  - SMF-28e, PANDA, etc.
  - HI / PM 1060 (1064nm optimized optical fibres)
  - Other specialty fibres, large-mode-area, etc.
- Potentially a hybrid electrical / optical connector with built-in safety interlock wires to disable laser if connector opened
- A factory terminated assembly to be fusion spliced into the LRU



# Glenair solution: Low-Loss Expanded-Beam Fibre Optic Connectors

- Expanded beam optical contacts incorporated into COTS MIL/AERO grade connector plugs and receptacles
- Novel active alignment of fibre optic contacts with precision laser-welded construction for high reliability



Glenair SuperNine Series



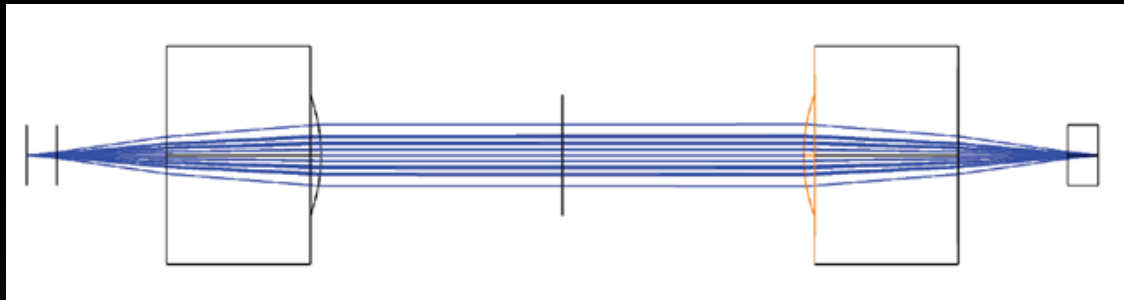
Glenair Series 806

Glenair Series 795



# Expanded beam with active alignment

- Expanding beam diameter from 9 $\mu\text{m}$  to  $>100\ \mu\text{m}$ 
  - Power density is reduced by factor of  $> (50/4.5)^2 \approx 120\text{X}$
  - 100W through our expanded-beam contact has same power density as 80 mW in a standard single-mode PC contact
- Soft axial and lateral tolerance; extreme tilt intolerance

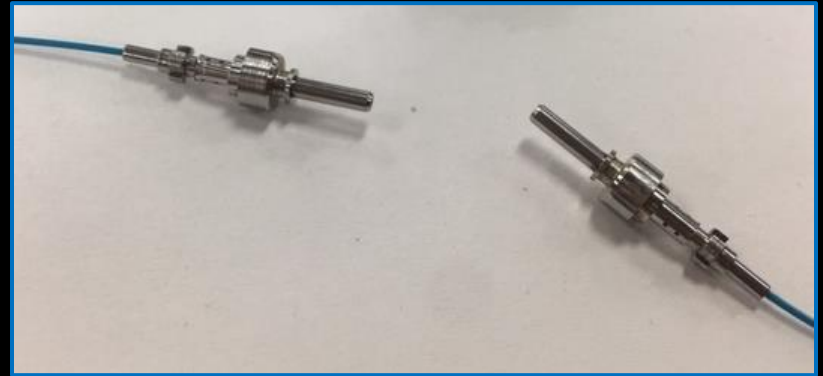


# Challenges

- Why has nobody done this yet?
  - It's very hard to do
  - $< 0.1$  degree tilt sensitivity requires extremely precise alignment
- Why is active alignment required?
  - 0.1 degree tilt causes  $>1.5$  dB loss.
  - 0.5 dB = 10% of 50W is 5W. Lost power causes localized heating of the optical contact and can result in damage
  - System designers need every 0.1 dB they can claw
- Require ultra-precise active alignment and attachment techniques to provide low enough loss in non-matched contacts

# Laser-Welded Expanded Beam Optical Contacts

- High-precision laser welding procedure with active alignment gives low loss  $<0.5$  dB
- Contacts align to each other through precision split-sleeve
- Install contacts into standard size 8 package to take advantage of COTS MIL/AERO connector systems.
- A size 16 version (for higher contact densities) is currently under development



Bare high-power contacts



Finally installed into cavity size 8 packaging

# High-Power Fibre Optic Connector Test Results

- Power handling test results
  - >20W (30W) CW 1064 nm PMF
  - 5W (10W) CW at 1550nm SMF
  - < 0.5 dB loss over temperature -40C to +85C
  - Maintained under 20Grms, x,y,z random vibration
- Active alignment system constructed and many contact pairs built using laser welding
  - SMF-28e at 1550nm
  - Nufern and Leikki PM fibre at 1064nm
  - 100/125um and 25/125um large-mode-area fibre versions are under development



# 1064nm PM Optical Fibre Preliminary Results

- 19W power handling with Nufern PM fiber at 1064 nm from -40C to +85C with loss < 0.5 dB and modest 6 - 8 C thermal rise
- Random vibration to 20Grms in D38999 with no measurable coupling change

Amp Current (A)	Chamber Temp (C)	Measured Power (W)	Measured Power (dBm)	Measured Baseline Power (W)	Measured Baseline Power (dBm)	Connector Loss (dB)	Ferrule Temp (C)
3	24	18.00	42.55	19.10	42.81	0.26	
3	-40	18.07	42.57	19.10	42.81	0.24	-30.9
3	85	18.04	42.56	19.10	42.81	0.25	93.3
3	-40	18.38	42.64	19.10	42.81	0.17	-30.9
3	85	18.20	42.60	19.10	42.81	0.21	92.5
3	-40	18.30	42.62	19.10	42.81	0.19	-30.5
3	85	18.30	42.62	19.10	42.81	0.19	93.8
3	-40	18.20	42.60	19.10	42.81	0.21	-30.5

# High-Power Fibre Optic Connector Summary

- Performed optical modeling to determine alignment tolerances required for < 0.5 dB loss
- Developed active alignment and laser-welded assembly process
- Verified
  - Losses < 0.5 dB
  - 20W power-handling capability at 1064nm with 6-8 C thermal rise (limit of test laser power)
  - 5W power-handling at 1550nm (limit of test laser power)
- Built prototype connectors using size 8 inserts based on existing D-38999 and rectangular D-sub connectors
- Smaller size 16 contact under development
- Product qualification testing is ongoing
- Engineering prototypes (Size 8) available now at 1064nm and 1550nm
- Looking partners to collaboration to tailor specific solutions for emerging applications

# More information...

- Ron Logan, VP & CTO, Photonics / Electronics  
[rlogan@glenair.com](mailto:rlogan@glenair.com)
- Davinder Basuita, UK / EU  
[dbasuita@glenair.com](mailto:dbasuita@glenair.com)
- Mike Dabrowski, USA & Asia  
[mdabrowski@glenair.com](mailto:mdabrowski@glenair.com)

## Thanks for your attention!



**MISSION-CRITICAL  
INTERCONNECT  
SOLUTIONS**



**EXPANDED-BEAM  
Eye-Beam® Power**  
Rugged, High-Power Fiber Optics for  
Directed Energy Applications

- Size #8 drop-in expanded-beam optical contact for rugged military/aerospace applications
- Powerful 20W and higher optical contact ideally suited for directed energy applications
- Turnkey incorporation in Glenair signature SuperNine, Series 792, and Series 806 Mil-Aero connectors
- Compatible with 1064nm polarize-lose-maintaining fiber with a 0.5 dB typical insertion loss
- Low temperature rise at peak power
- Signature assembly process optimizes optical alignment for mission-critical reliability

A major impediment to the deployment of directed energy technology utilizing high-power lasers has been the lack of a connectivity solution to facilitate line replaceable unit (LRU) maintenance in the field. Glenair is pleased to introduce Eye-Beam Power, the world's first ruggedized, high-optical power terminus for multi-pin connectors. Leveraging our field-proven expanded beam technology, Eye-Beam Power utilizes a novel expanded optical beam approach to create a robust and stable optical connection in any environment. The industry-standard size #8 contact module allows Eye-Beam Power to be loaded into a multitude of connector form factors such as Glenair Signature SuperNine, Series 792, and Series 806 Mil-Aero.

Glenair has also developed a signature assembly technology that optimizes alignment giving a reliable cable assembly that meets the most stringent Mil-Aero industry requirements. Our 20W and higher optical power solution is compatible with standard polarization-maintaining 1064nm fiber, provides 0.5dB typical insertion loss, and features a low temperature rise at peak power, minimizing the need for additional heat sinking or thermal management beyond that of a simple copper wire overbraid. 1550nm and other wavelengths can also be supported, contact the factory for additional information.

© 2021 Glenair, Inc. - 1211 Air Way, Glendale, CA 91201 - 818-247-6000 - [www.glenair.com](http://www.glenair.com) - U.S. CAGE code 06224 Rev. 04/23/21