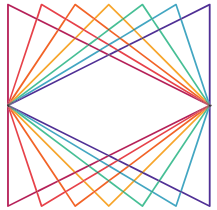


OPIPHOTONICS

Fiber based cables for ultrashort pulse delivery

Dr. Francesco Pescarmona

Swiss Photonics Workshop
Specialty Optical Fibers

Outline

OPIPHOTONICS

- Introduction: OPI
- Motivations
- Photonic Crystal Fibers
- OPI's cable
- Experimental Results

Who we are

OPIPHOTONICS

Diodes

High power laser diode packaging

Delivery

Free-space and fiber based delivery

Specials

Special projects for high power photonics

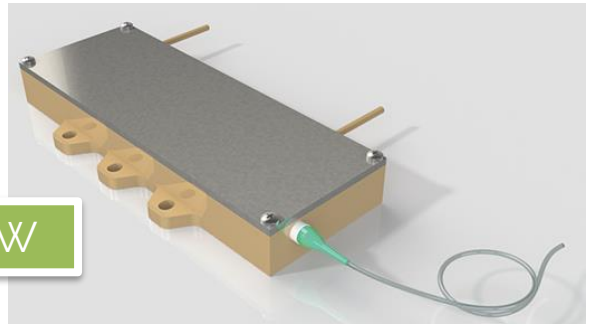
Who we are

OPIPHOTONICS

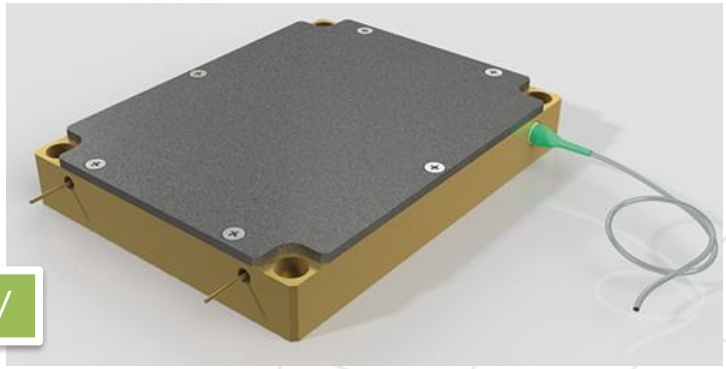
Diodes

Delivery

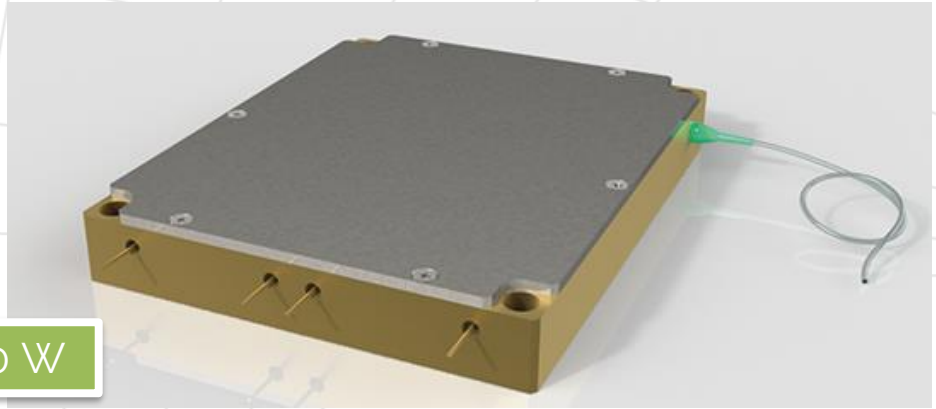
Specials



100 W



200 W



300 W

Who we are

OPIPHOTONICS

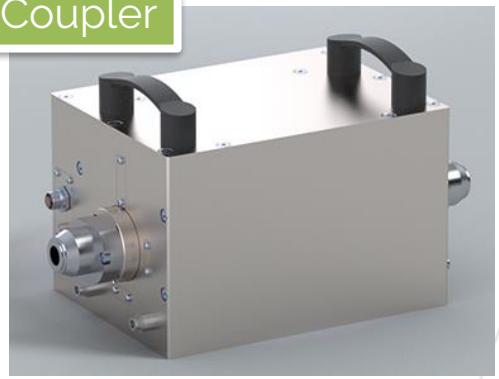
Diodes

Delivery

Specials

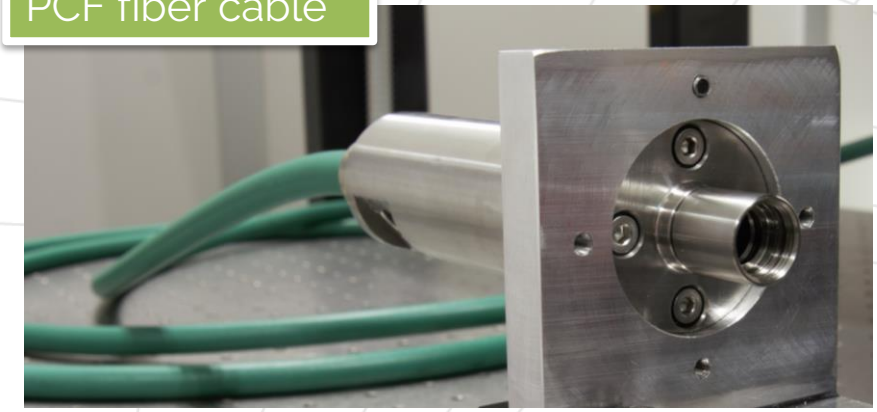
Collimator

Coupler



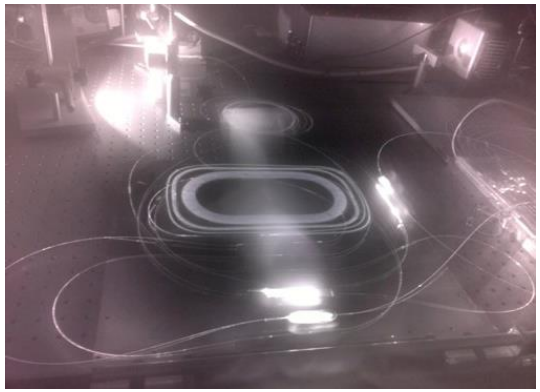
Switch

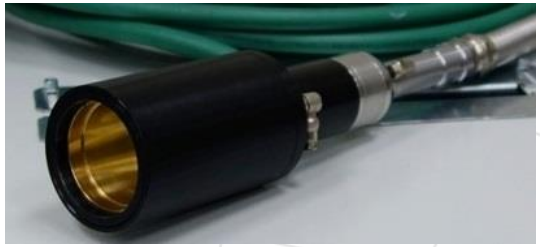
PCF fiber cable

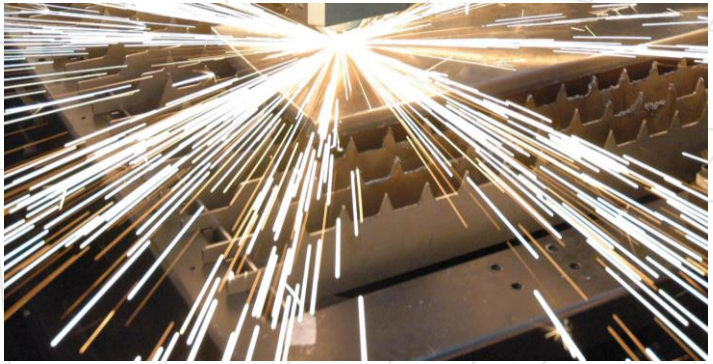


Who we are

OPIPHOTONICS







Motivations

OPIPHOTONICS

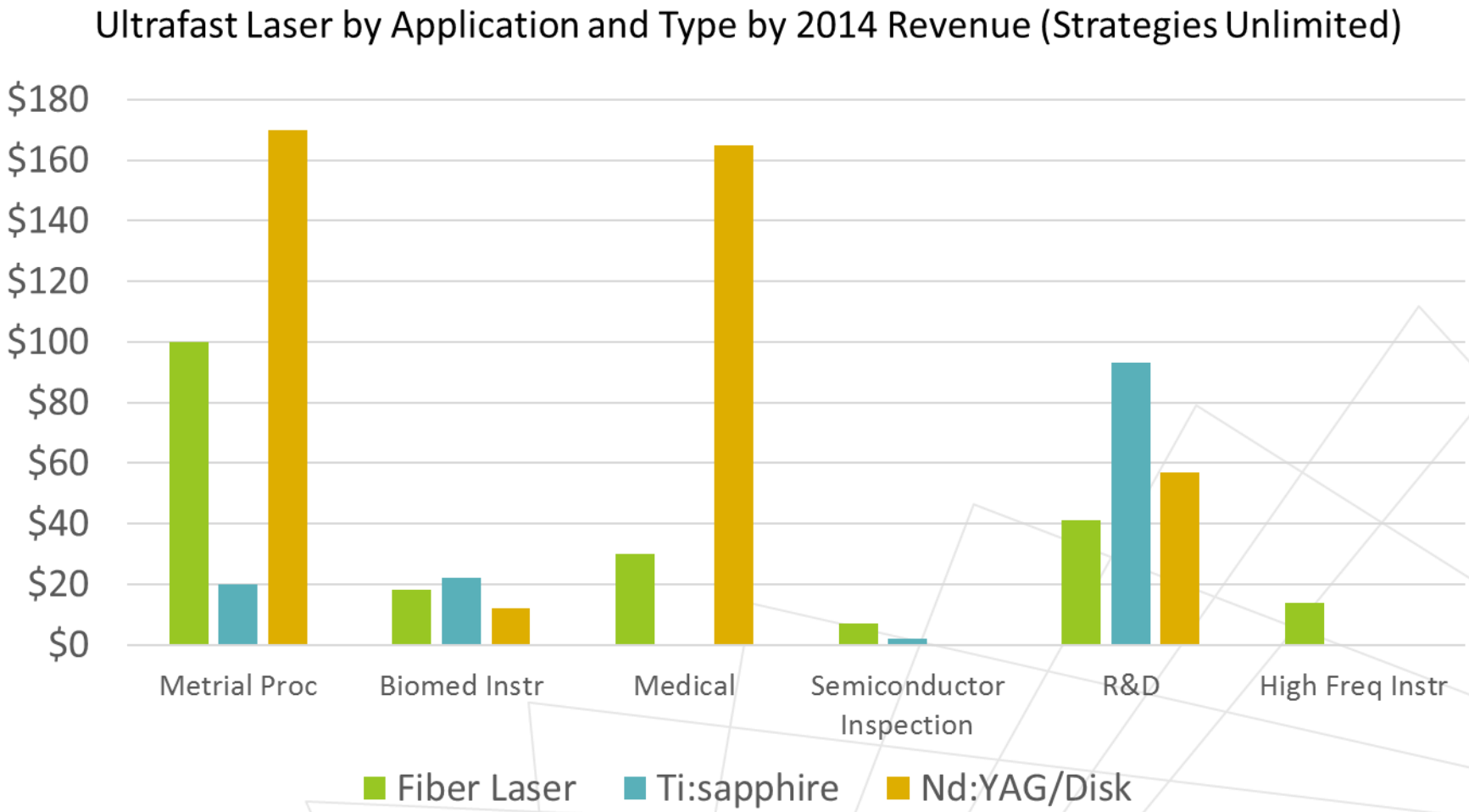
Total Ultrafast Market 2014 to 2019 (Strategies Unlimited)

Summary	2014	2015	2016	2017	2018	2019	CAGR 2015-2019
Femtosecond							
Units	2'678	3'227	3'836	4'475	5'188	6'000	16,8%
Revenues (M$)	548	640	742	844	958	1'088	14,2%
Picosecond							
Units	1'417	1'542	2'015	2'437	3'028	3'572	23,4%
Revenues (M$)	222	210	239	273	310	352	13,8%
Total							
Units	4'096	4'770	5'851	6'912	8'215	9'572	19,0%
Revenues (M$)	769	850	981	1'117	1'268	1'440	14,1%

Strategies Unlimited™ A Research Unit of PennWell

Motivations

OPIPHOTONICS



Motivations

OPIPHOTONICS

Material processing Ultrafast Laser Summary 2014-2019

Materials Proc	2014	2015	2016	2017	2018	2019	CAGR 2015 to 2019
Femtosecond							
Units	482	623	767	930	1,106	1,295	20.1%
Prices ($)	$285,000	$256,000	$237,000	$221,000	$208,000	$199,000	-6.1%
Revenue ($ Million)	$137.5	$159.5	$181.8	$205.4	$230.1	$257.7	12.7%
Picosecond							
Units	1,075	1,142	1,572	1,946	2,486	2,969	27.0%
Prices ($)	$162,000	$136,800	$115,200	$108,000	$97,200	$93,600	-9.1%
Revenue ($ Million)	$174.2	$156.2	$181.2	$210.1	$241.7	$277.9	15.5%
Total							
Units	1,557	1,764	2,340	2,875	3,592	4,264	24.7%
Prices ($)	$200,094	$178,881	$155,134	$144,531	$131,317	$125,608	-8.5%
Revenue ($ Million)	$311.6	$315.6	$362.9	$415.6	$471.7	$535.6	14.1%

Source: Strategies Unlimited

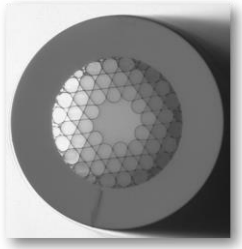
Ultra short pulse delivery

OPIPHOTONICS

Today: free-space → Fiber Delivery → Applications

Today: pulsed lasers require **free-space** delivery systems

+



Solution: **industrial grade cable** based on innovative optical fibers

Aim: facilitating **material processing** applications using **robots**

Solution: Hollow core photonic crystal fiber

Traditional fiber

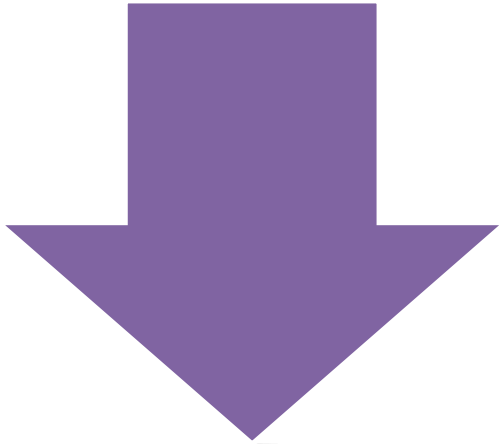
OPIPHOTONICS

Cheap

Robust

Reliable

Low propagation loss



Non linear effects

Wavelength dependent single mode behavior

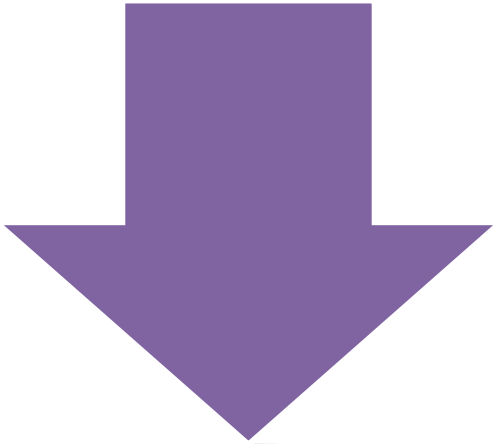
Damage threshold

Photonic Crystal Fiber

OPIPHOTONICS

High design flexibility

Tailored non linear effects



Difficult manufacturing

High cost

High loss

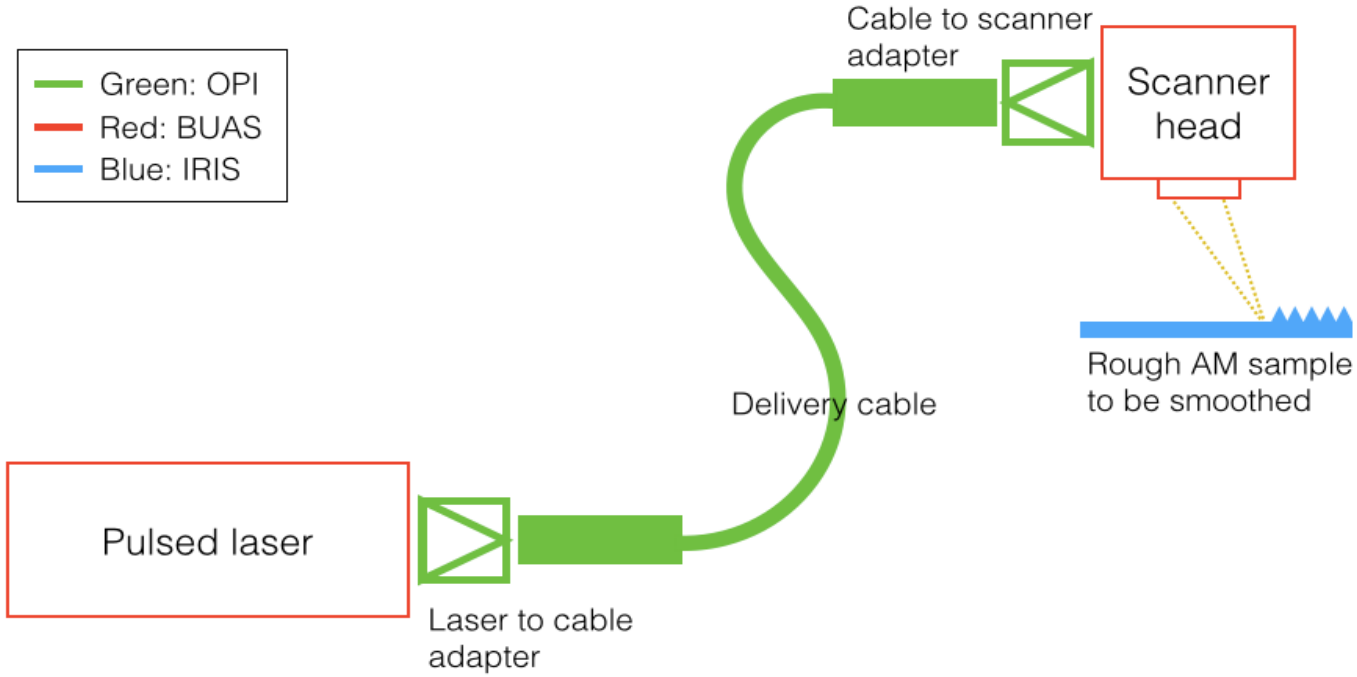
Difficult handling (fragility)

Industrial-grade delivery cable

OPIPHOTONICS

appolo

Ultra short pulses delivery cable for industrial processing



OPIPHOTONICS

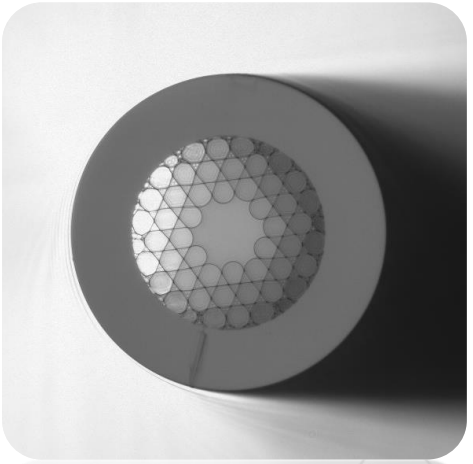
IRIS

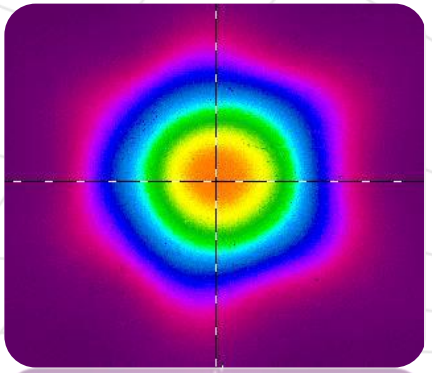
FH
Bern University of Applied Sciences

Industrial-grade delivery cable

OPIPHOTONICS

- Photonic Crystal Fiber
  - Large core size
  - Nearly single mode
  - Air guiding
  - High laser damage threshold
  - Operating wavelengths 900 ÷ 1100 nm
- Challenges
  - Low NA: alignment optimization and stability
  - Cost reduction

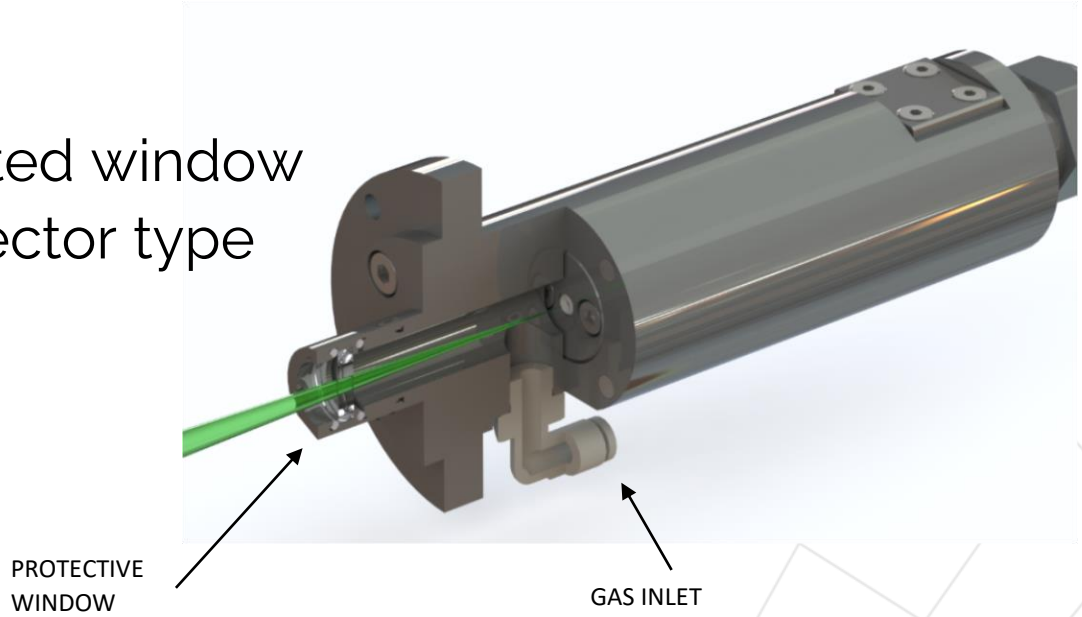




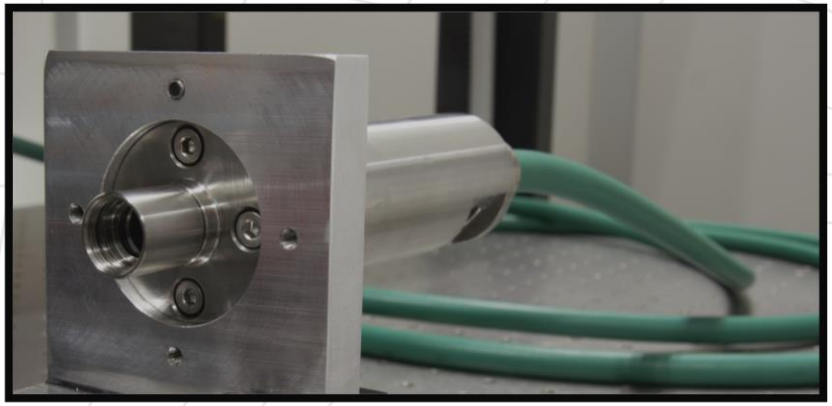
Industrial-grade delivery cable

OPIPHOTONICS

- **Connector**
  - High power AR-coated window
  - Customizable connector type
  - Safety interlock
  - Gas inlet



- **Cable**
  - Inner Sheath: Stainless steel
  - Outer Sheath: Flexible reinforced plastic
  - Bending radius > 250 mm
  - Maximum length: 10 m
  - Safety interlock



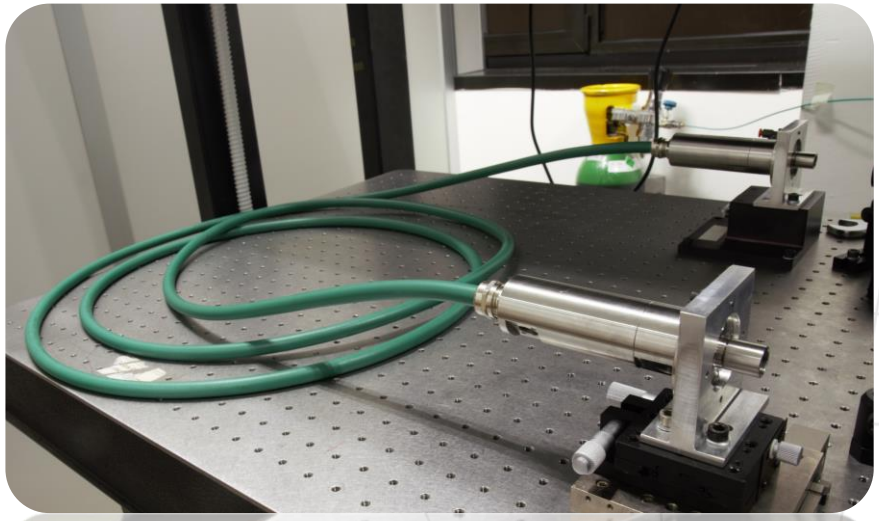
Laser beam coupling

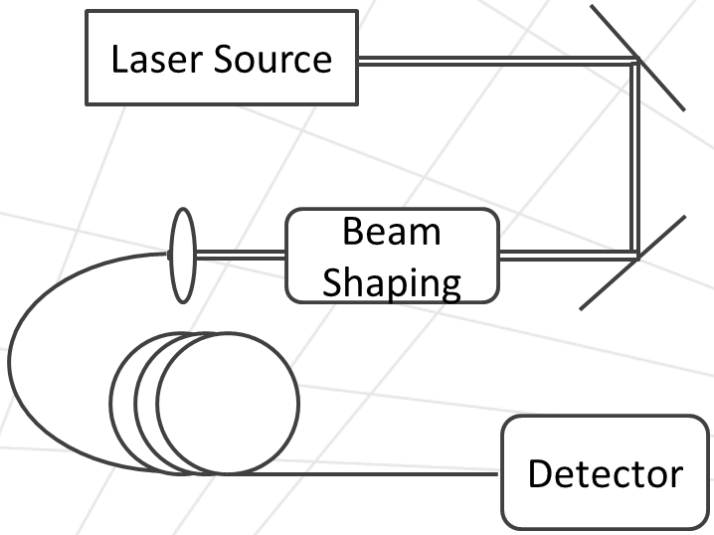
OPIPHOTONICS

Fiber requires **high** alignment accuracy

Proprietary alignment system with sub-micron positioning accuracy

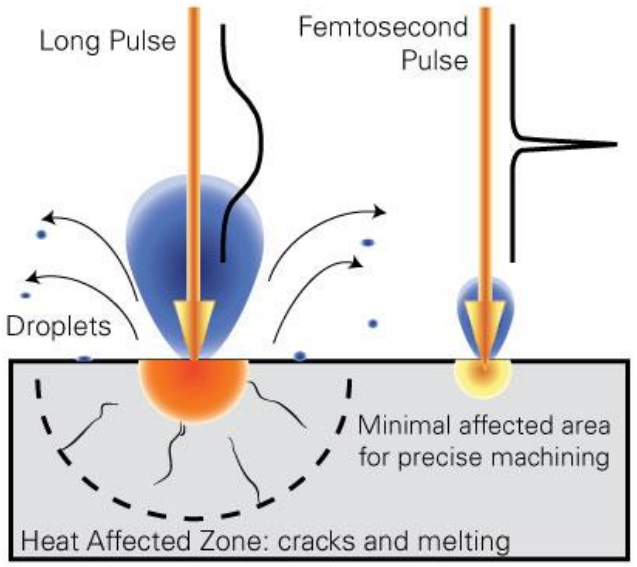
Long term stability *(critical)*





Cable testing conditions

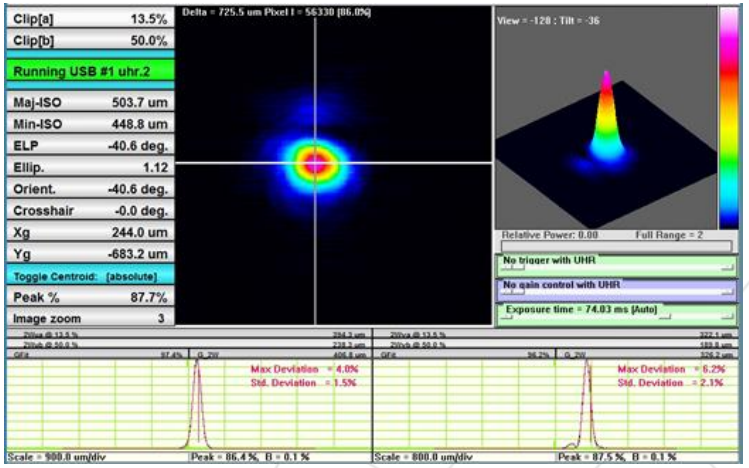
- Tested at:
  - 10 ns, 20 kW peak power
  - 150 ns, 1mJ pulses
  - 10 ps, 300mJ pulses
- Source $M^2 < 1.2$
- No measurable pulse broadening (down to ~ 10 ps)

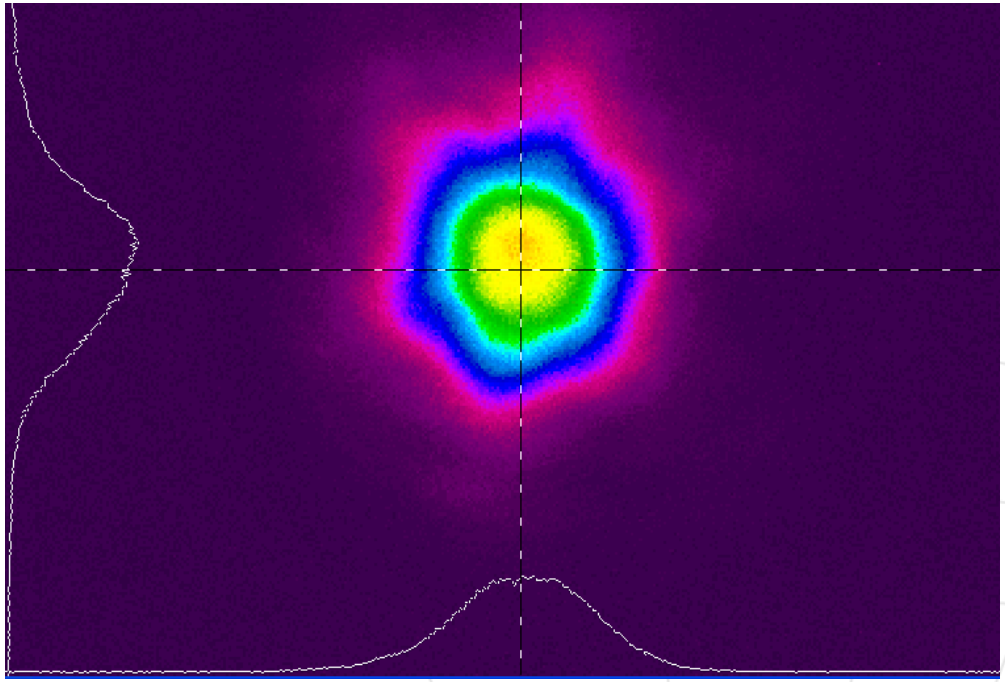


- No fiber damage
- Very good optical performance
- Output Polarization Extinction ratio > 30 dB
- Dynamic usage is critical: testing different configurations and armors

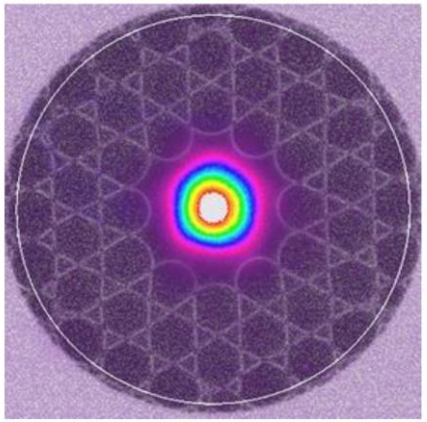
Fiber output beam profile

- Typical M^2 = 1.2 ÷ 1.3
- Coupling efficiency > 90%





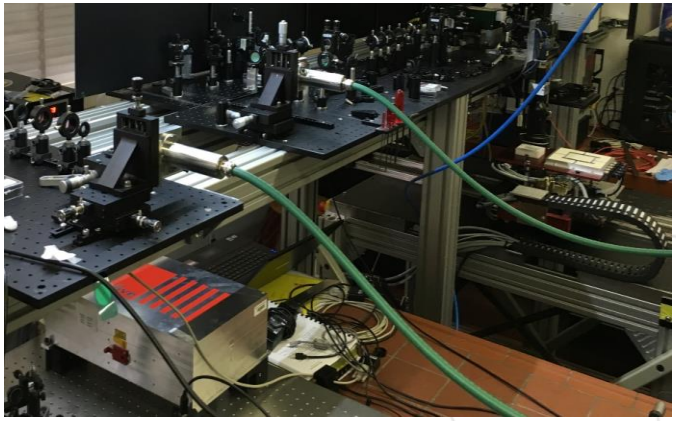
Typical near field image of the cable output mode

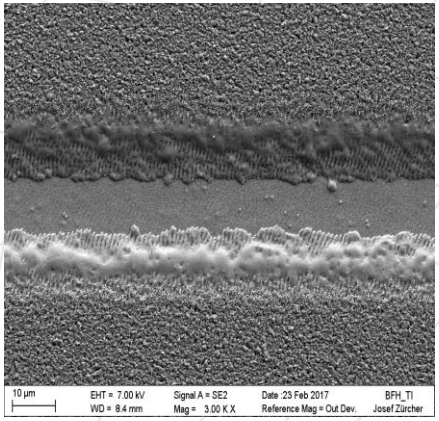


Material processing application

OPIPHOTONICS

- Solar cell scribing tests:
  - Bern University of Applied Sciences (BUAS) has developed a lab machine for production of thin film photovoltaic modules (CIGS solar cells, high-throughput P2 process achieved by shaping the beam waist to a linear focus)
  - Cells have been scribed with and without the cable
  - Results (cell scribing efficiency) have shown no apparent change in performance introduced by the cable





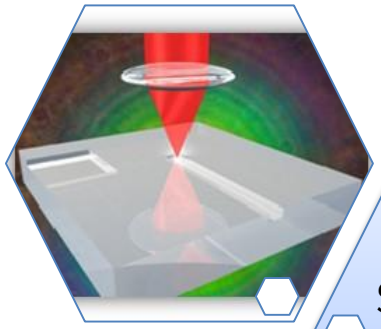
Bern University
of Applied Sciences

Innovative applications

OPIPHOTONICS

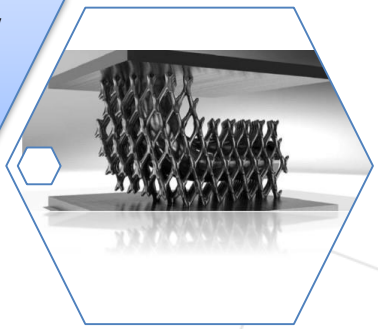
SYMBIONICA

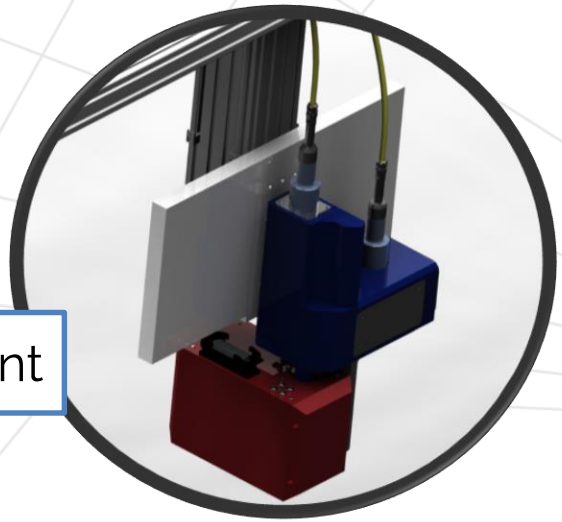
BOREALIS



Subtractive
Ablation

Additive
3D printing





Metal powder sintering + surface refinement

THANK YOU!

appolo