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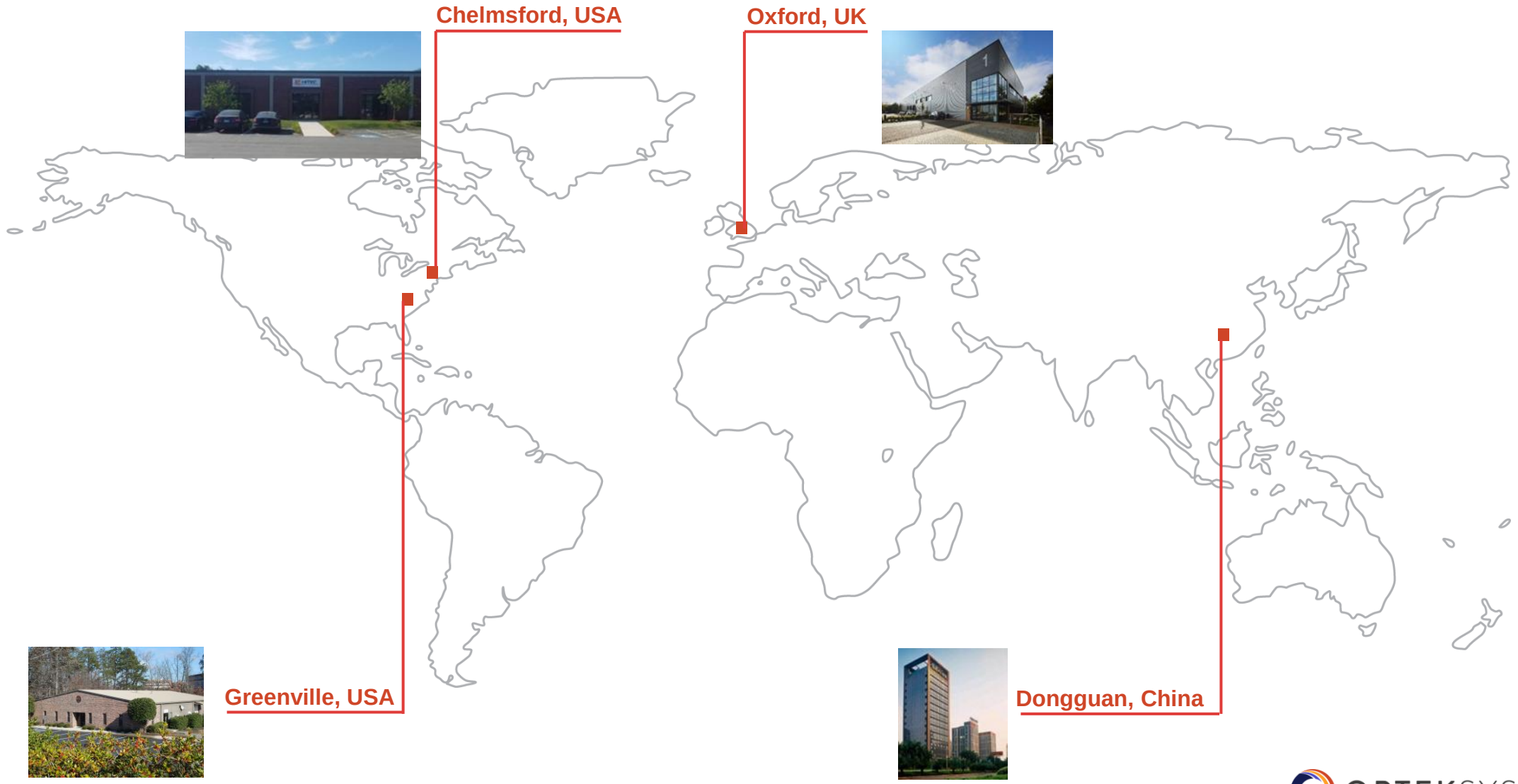
Laser Processing of Optical Fibers and Components

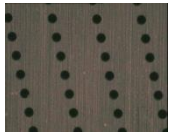
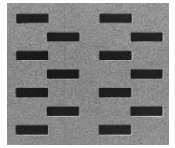
Chris Randon

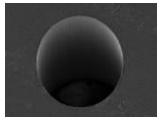
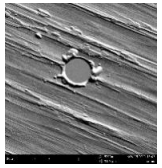
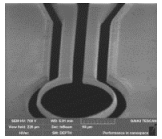
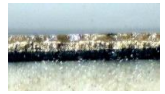
EPIC TechWatch 25 September 2024

Laser Micromachining Across the world

Global Presence



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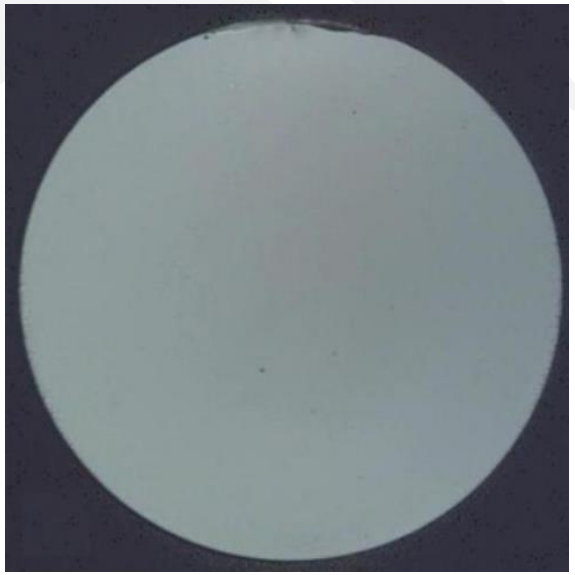
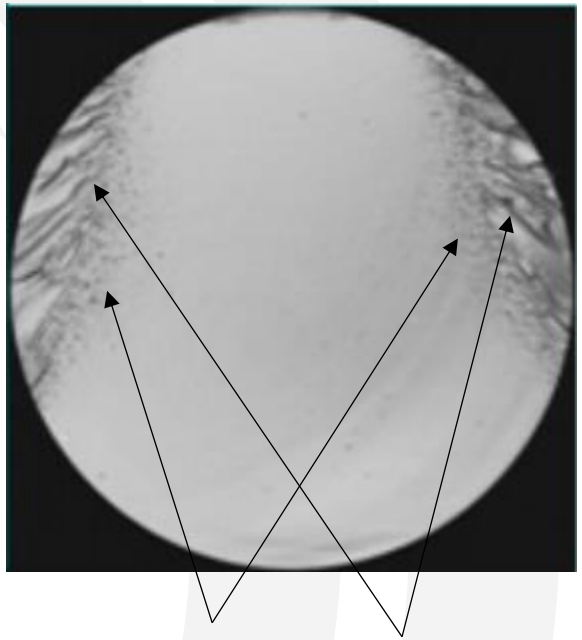
Mechanical Cleaves

- Prone to tool wear
- Needs skill and attention to detail

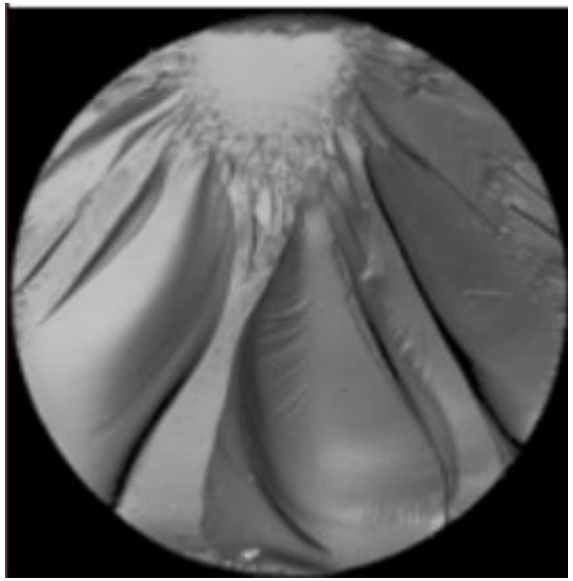
The Good

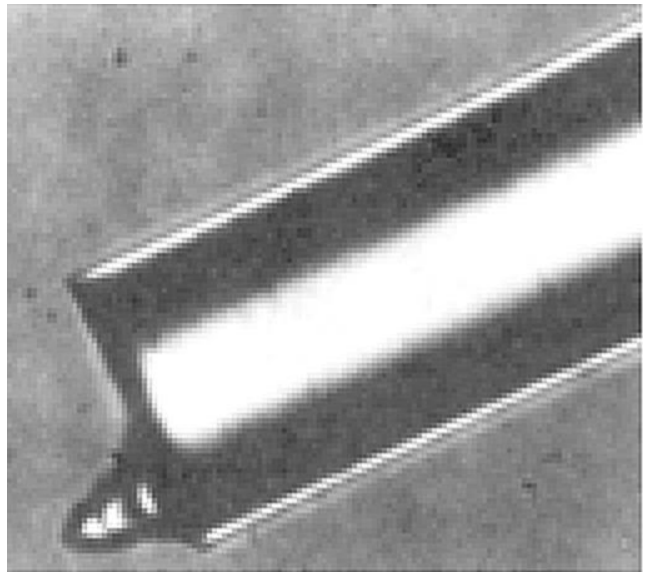


The Bad



The Ugly

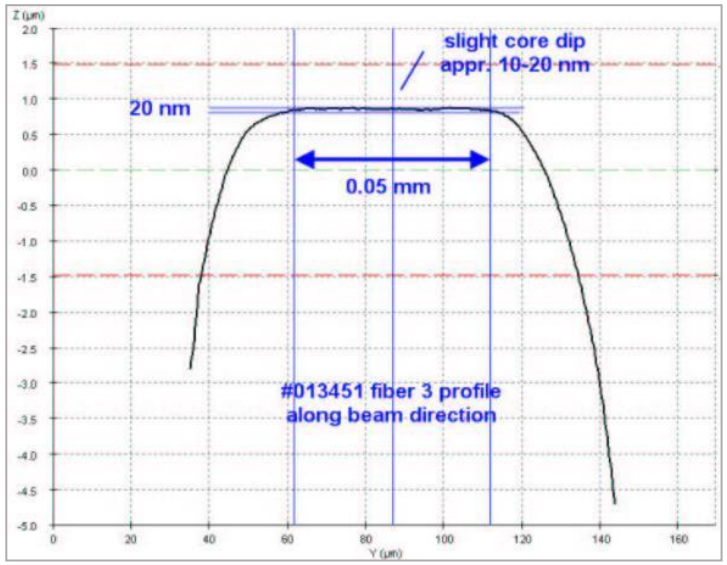




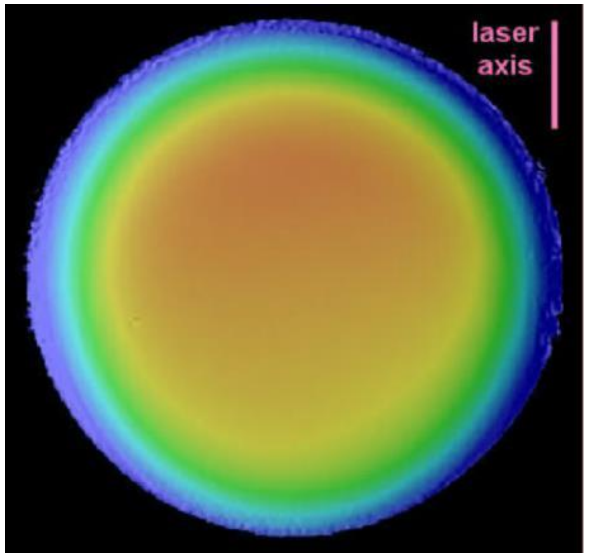
- But many people use it in large scale production

Laser Cleave

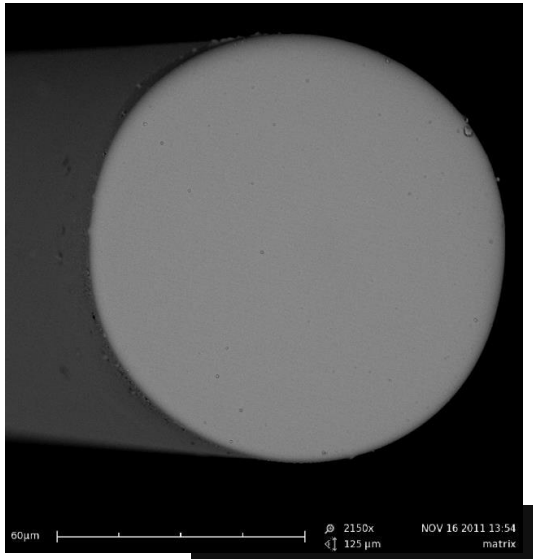
- Contact free
- Not Prone to tool wear
- De-skilled and well suited to automation



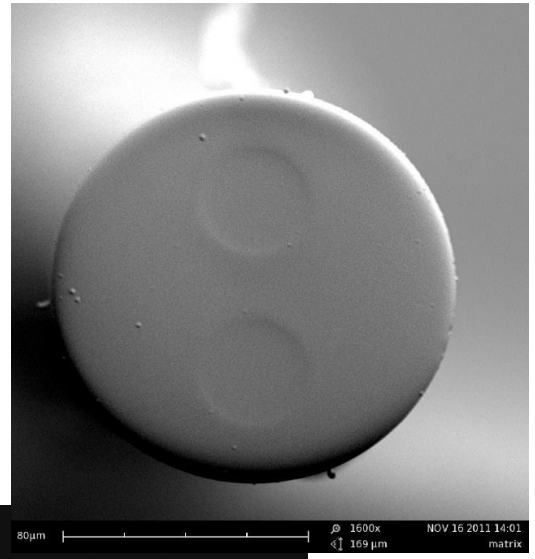
MM



SM

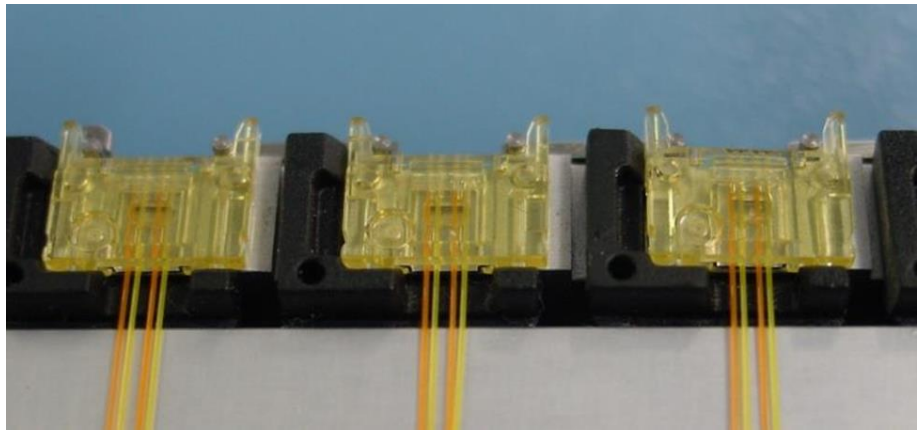


PM (Panda)



- Different geometry from Mechanical
- Corners are rounded

Active Optical Cable Production



AOC

Optical HDMI

USB

Thunderbolt

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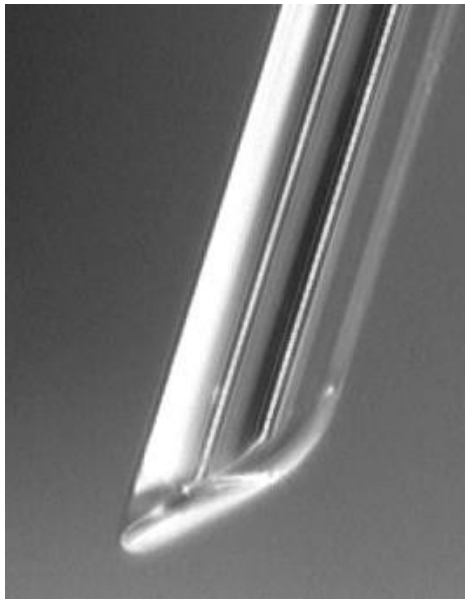
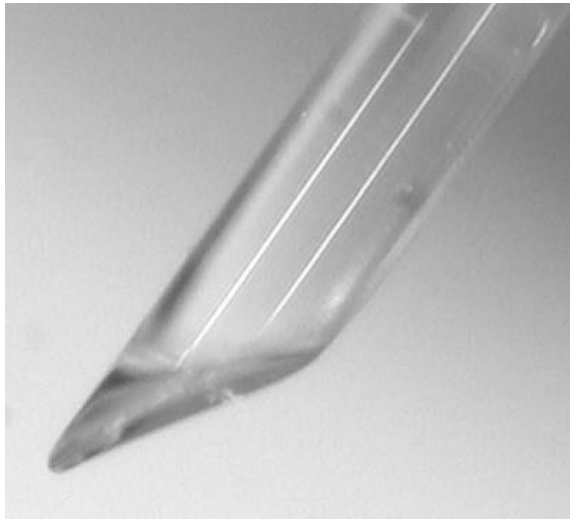
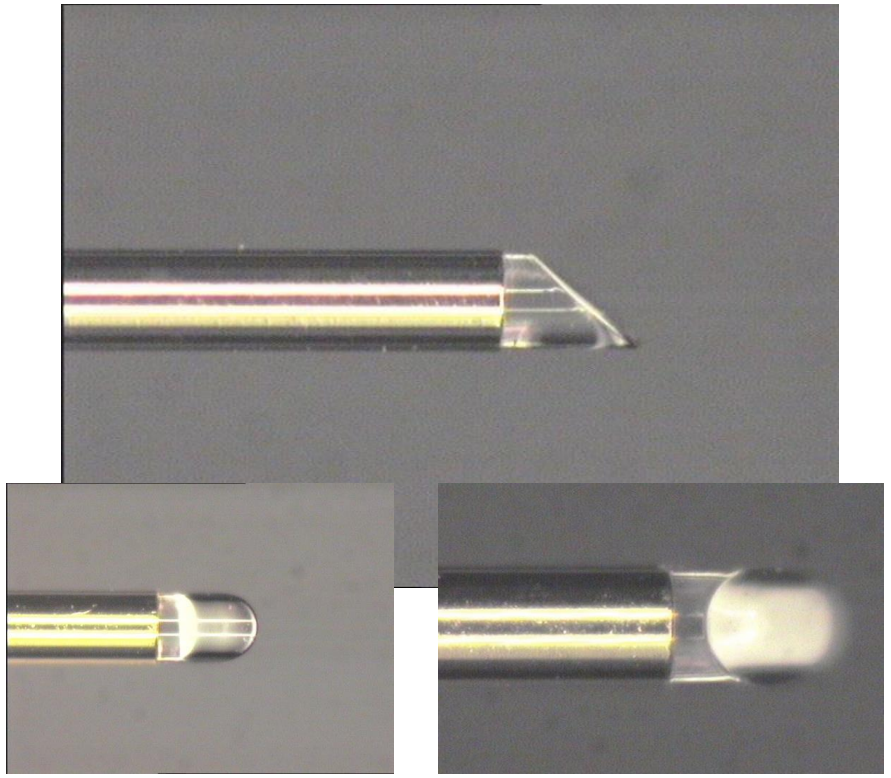
Laser Cleaves - Angles

- Range of angles possible
- Can orientate angle with respect to external feature
- High-angle cleaves possible
- Good reproducibility



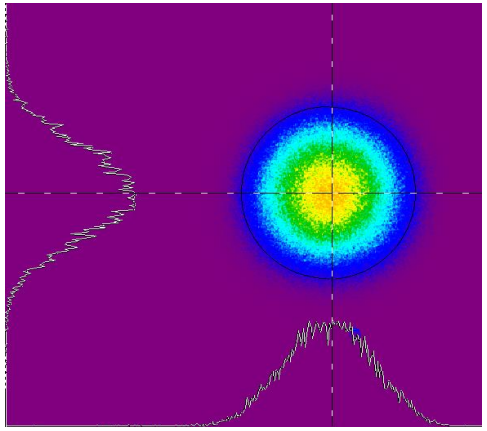


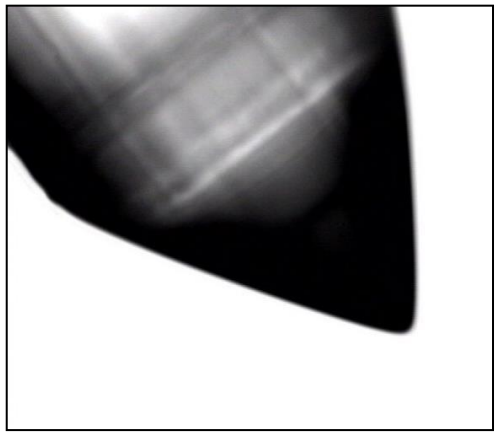
- Cleave to within <50µm of metalisation

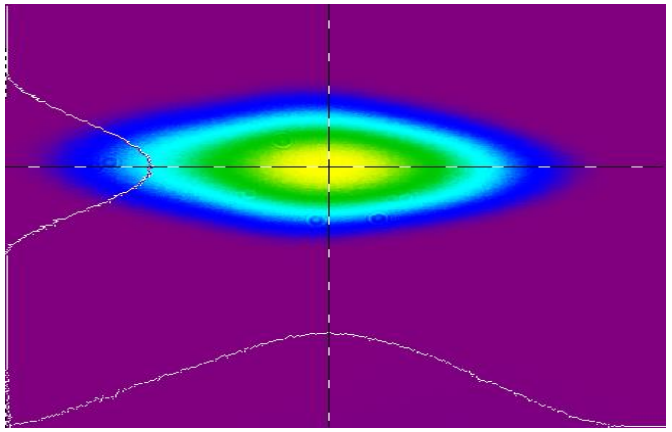


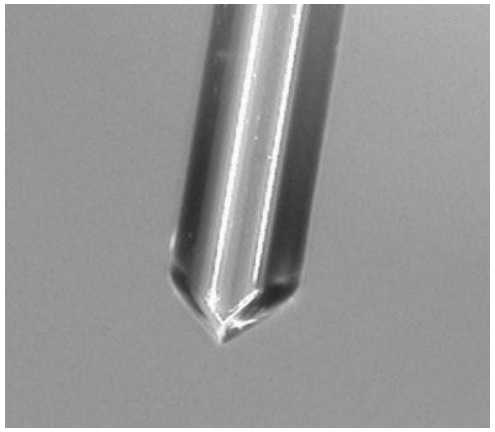
Laser Machined Lenses

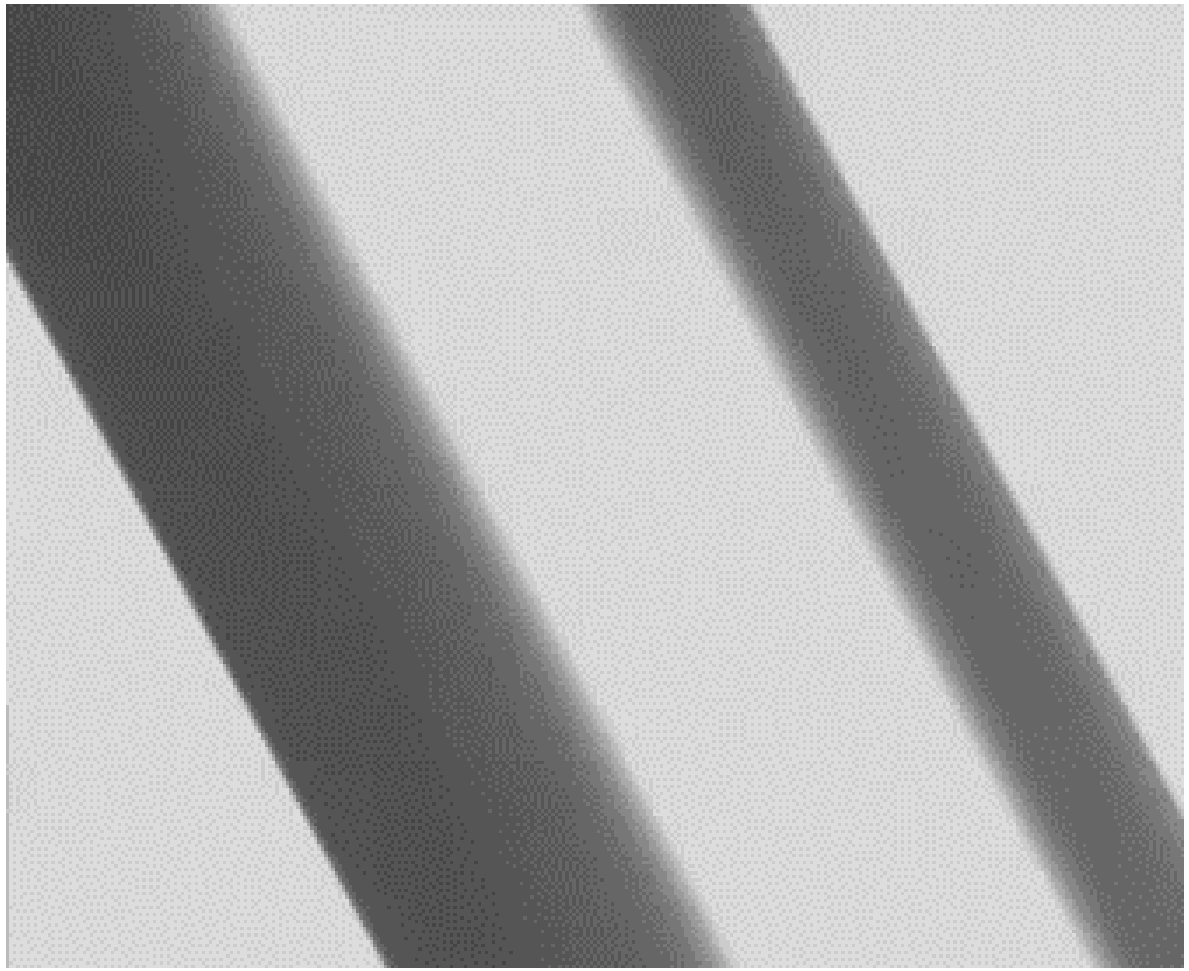
- Spherical, Aspheric, Wedge, Cylindrical lenses
- Post-process inspection reduced
- Applicable to PM fiber
- Can machine thru’ buffer
- Active Feedback











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Laser Cleave - Pre-Polish

Fiber Termination

Why Laser Cleave?

Automation is the key to reliable and economical high-volume production because it improves product quality, consistency, yield and throughput.

Problems

- Mechanical cleaving

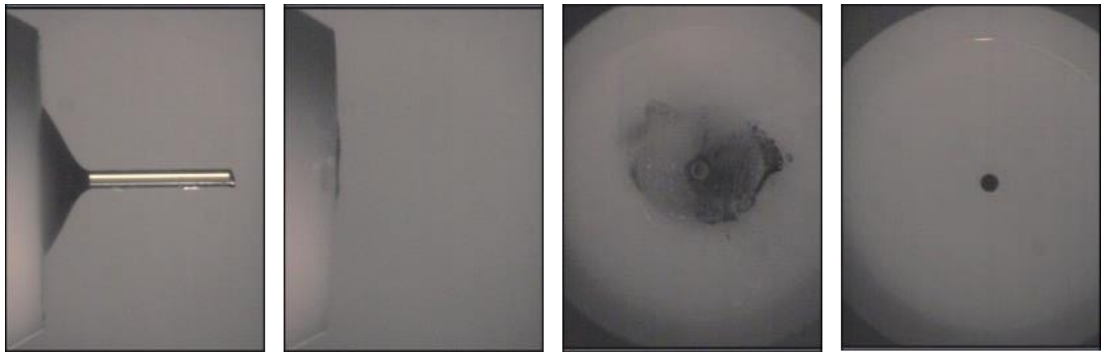
  operator and tool-dependent
- Epoxy Bead size

  operator and process-dependent quality
- Polishing

  sub-optimal initial conditions
- Connector/Fiber-specific challenges
- Compromised First Pass Yield, Throughput, Quality, and Cost!

Solution

- Integrated de-nubbing* and epoxy removal offered by laser cleave



* also called air-polish or greening

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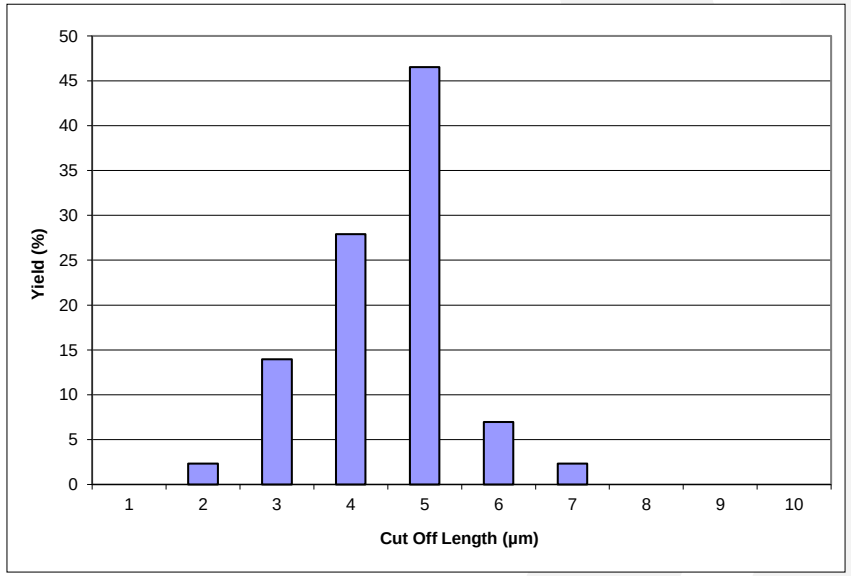
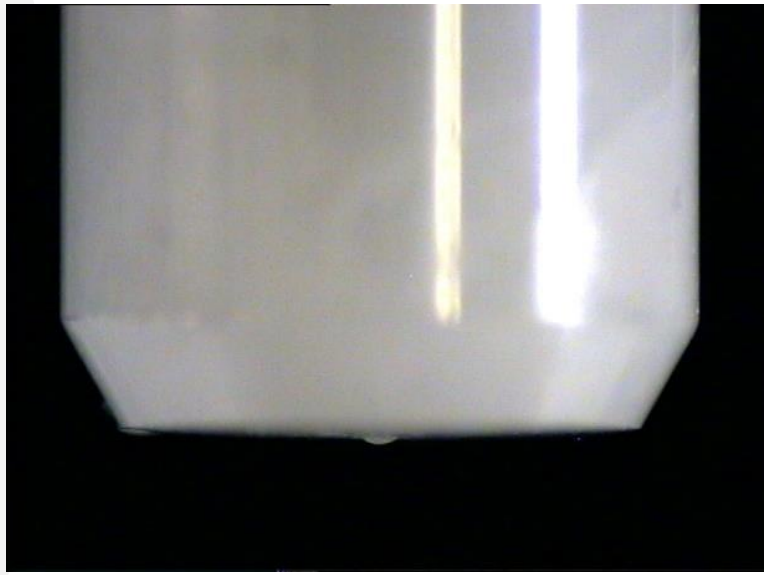
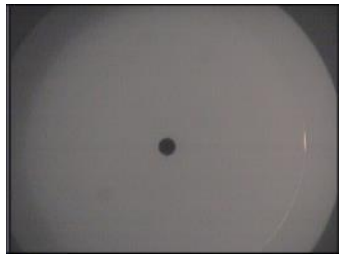
1500 Machine

- Average cut lengths down to 20-25µm (MU)
- Typical tolerance <±5µm (1σ) (dominated by ferrule & epoxy)
- Consistent short cleave length
  - Higher yield
  - Less polishing
  - Less Consumables
  - Better utilisation of polishing real-estate







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But this is a Technology Update

Why are we discussing a 20-year-old Technology?

Refreshed and updated, this same technology improves processes of existing and future interconnect solutions.

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Laser Strip & Cleave - Pre-Polish

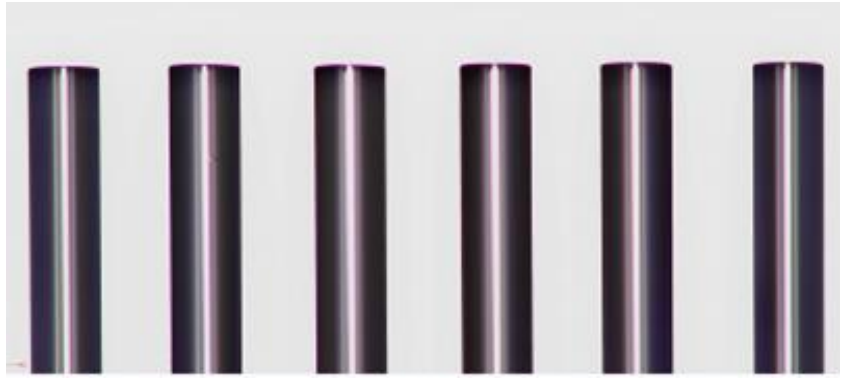
Multifiber Termination

LCS500 – Laser Cleave and Strip

Cleaving for the TMT age

(but offers advantages for MPO)

Low flare ribbon processing suitable for placement in v-grooves, silicon photonics and co-packaged optics.



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LCS500 – Laser Cleave and Strip

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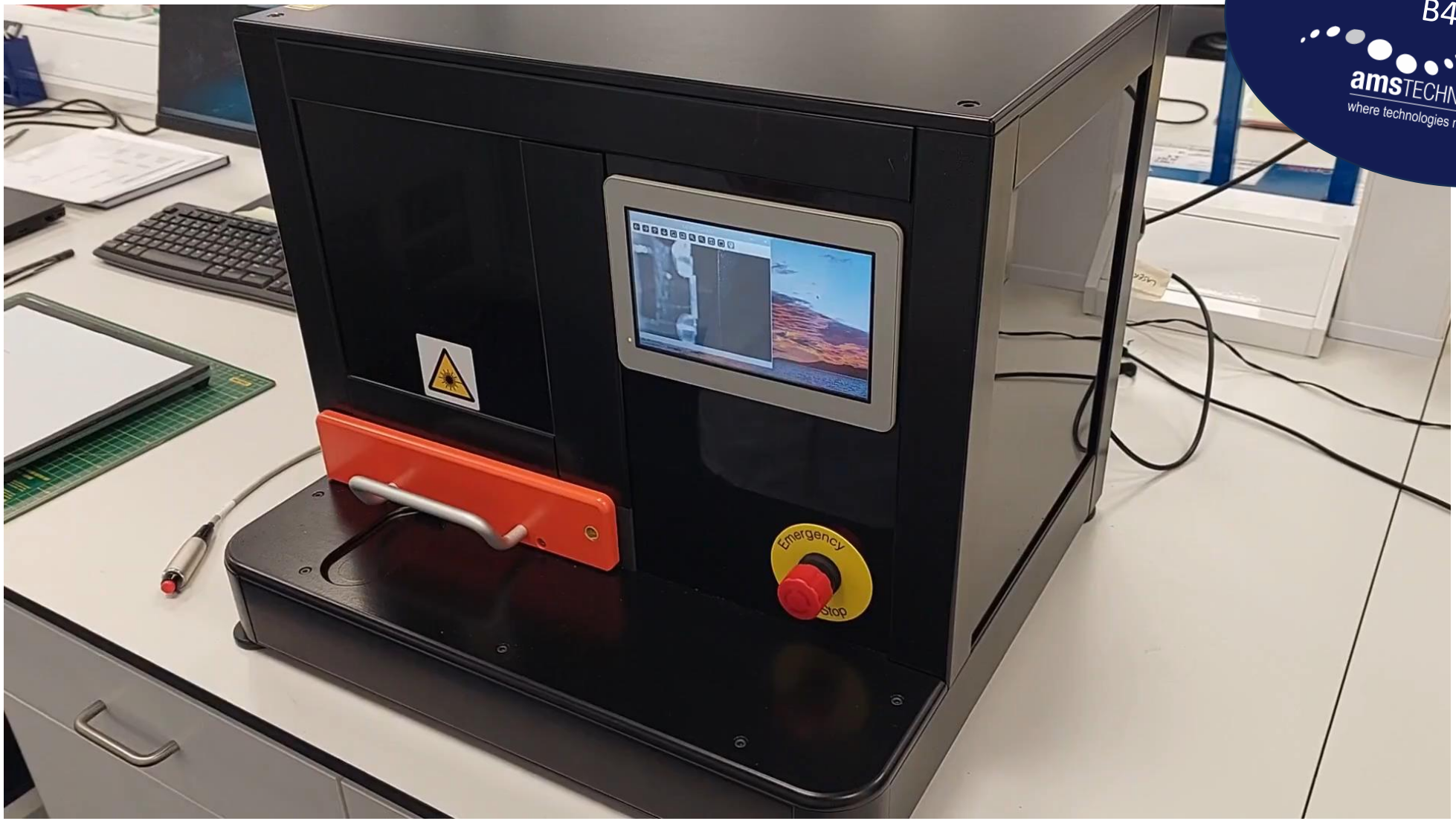

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LCS500 – Laser Cleave and Strip

Low flare ribbon processing suitable for placement in v-grooves or into MPO-Ferrule

Laser Cleaved to length and optimal protrusion

Insertion with less epoxy also suitable for vacuum processed ferrules

Ready for polishing right after curing, no additional cleaving required.

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Direct Connection

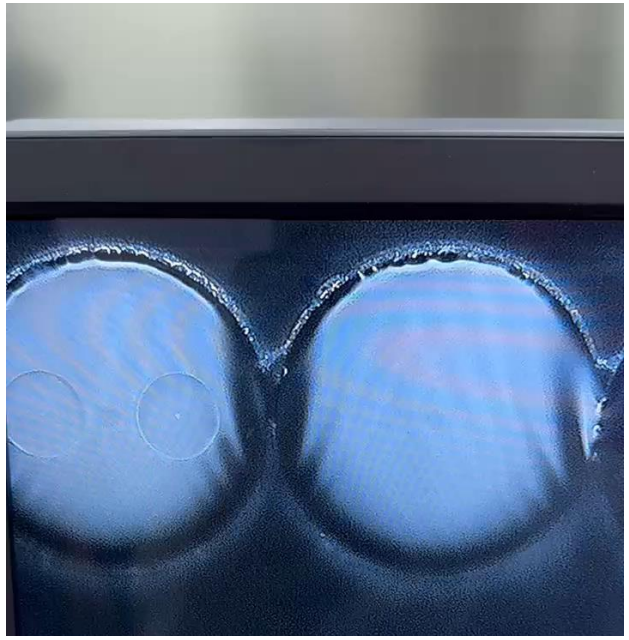
Active Optical Cables, Silicon Photonics and PIC’s

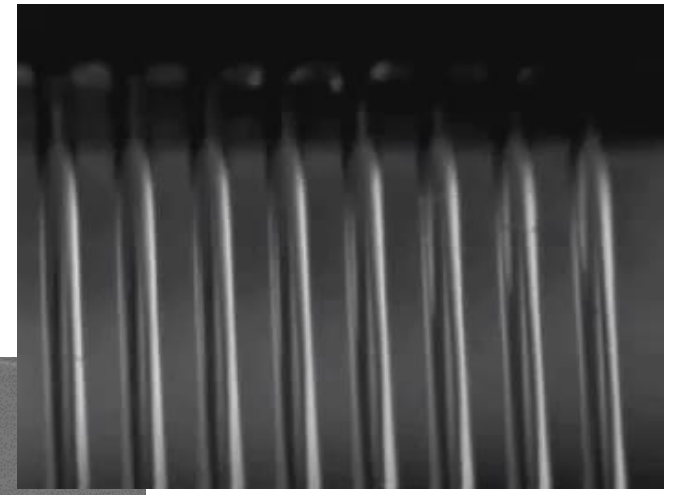
Refreshed and updated

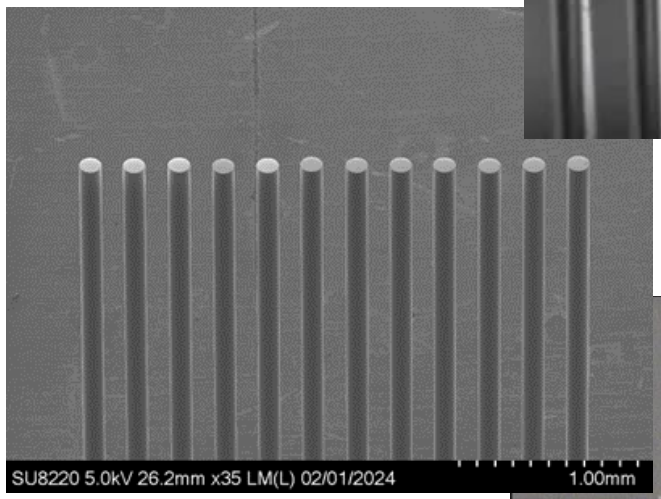
- Very low flare processing

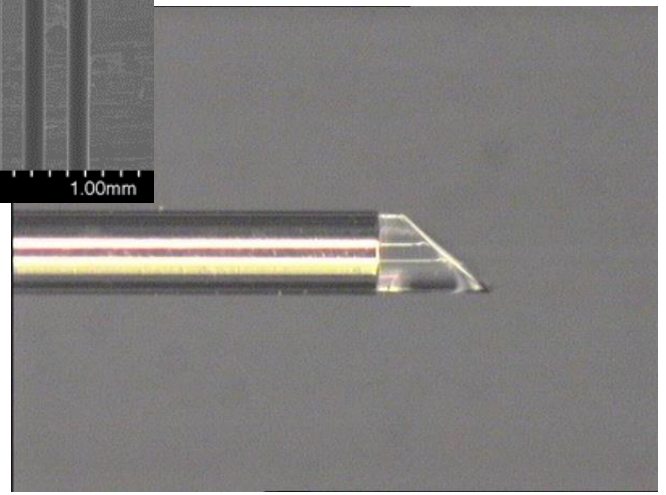
- Angled cleaves
  - 0° to 50°

- 127µm pitch processing









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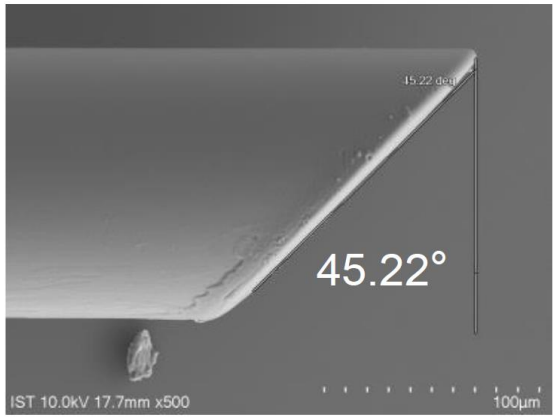
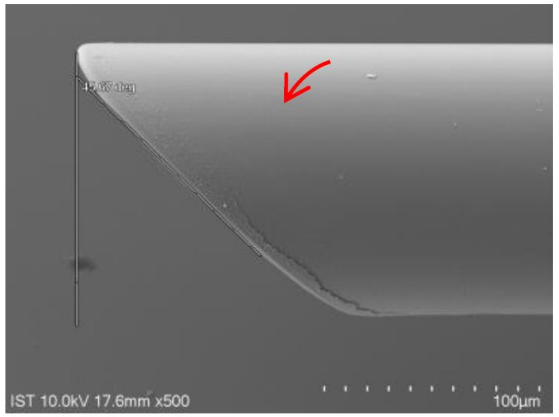
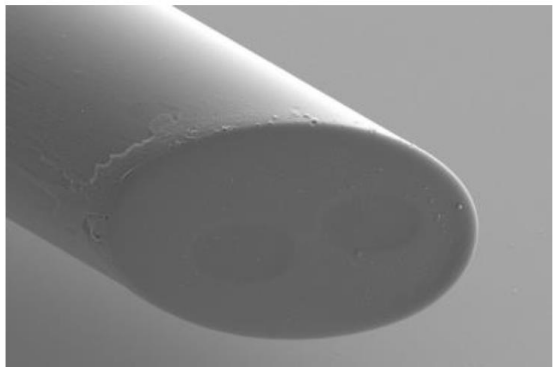
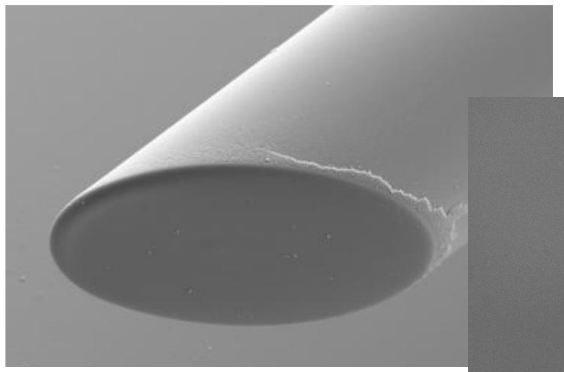
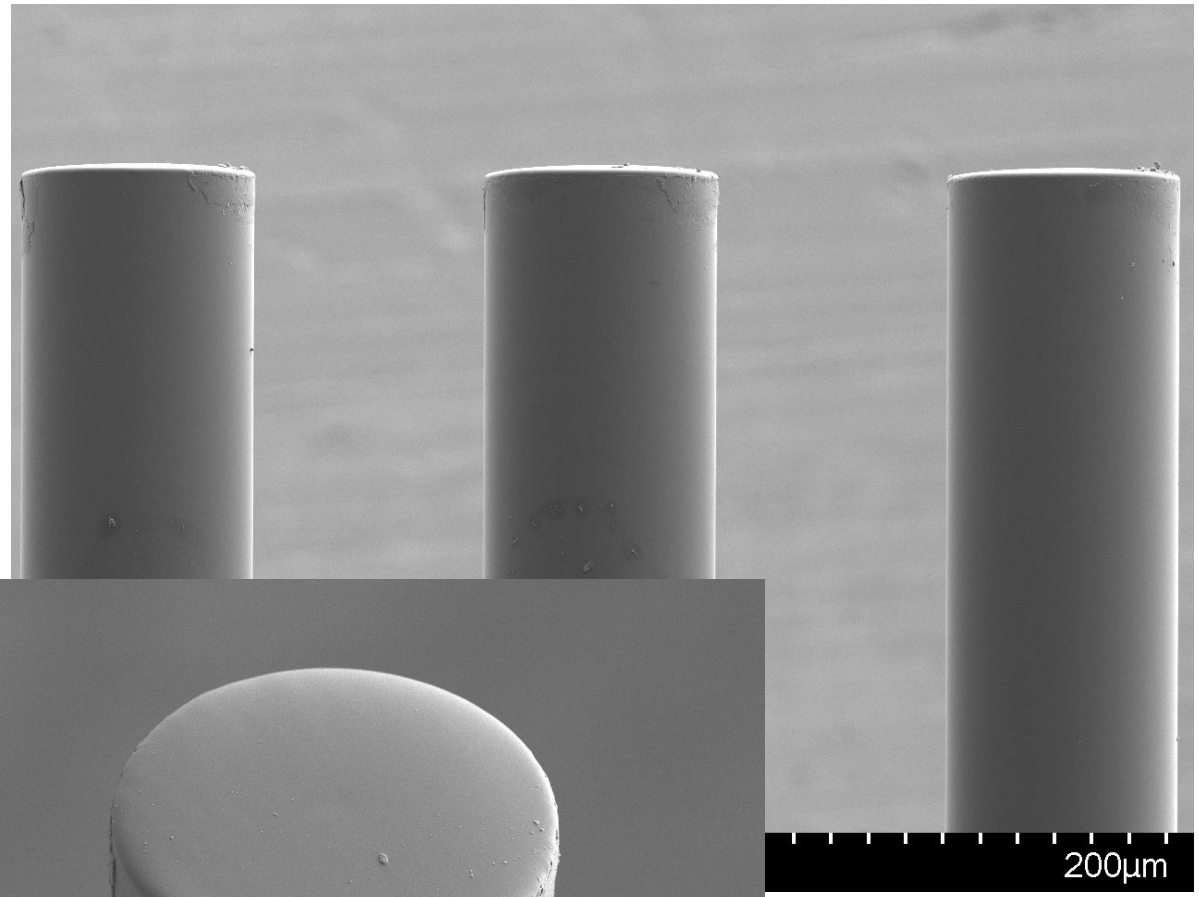
Low Flare – Even on Angles

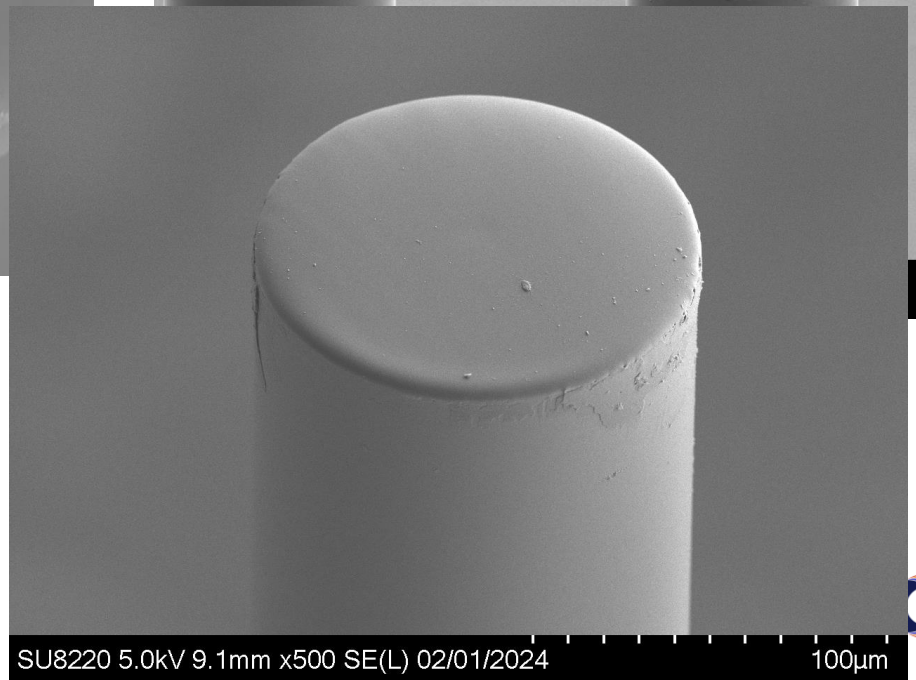












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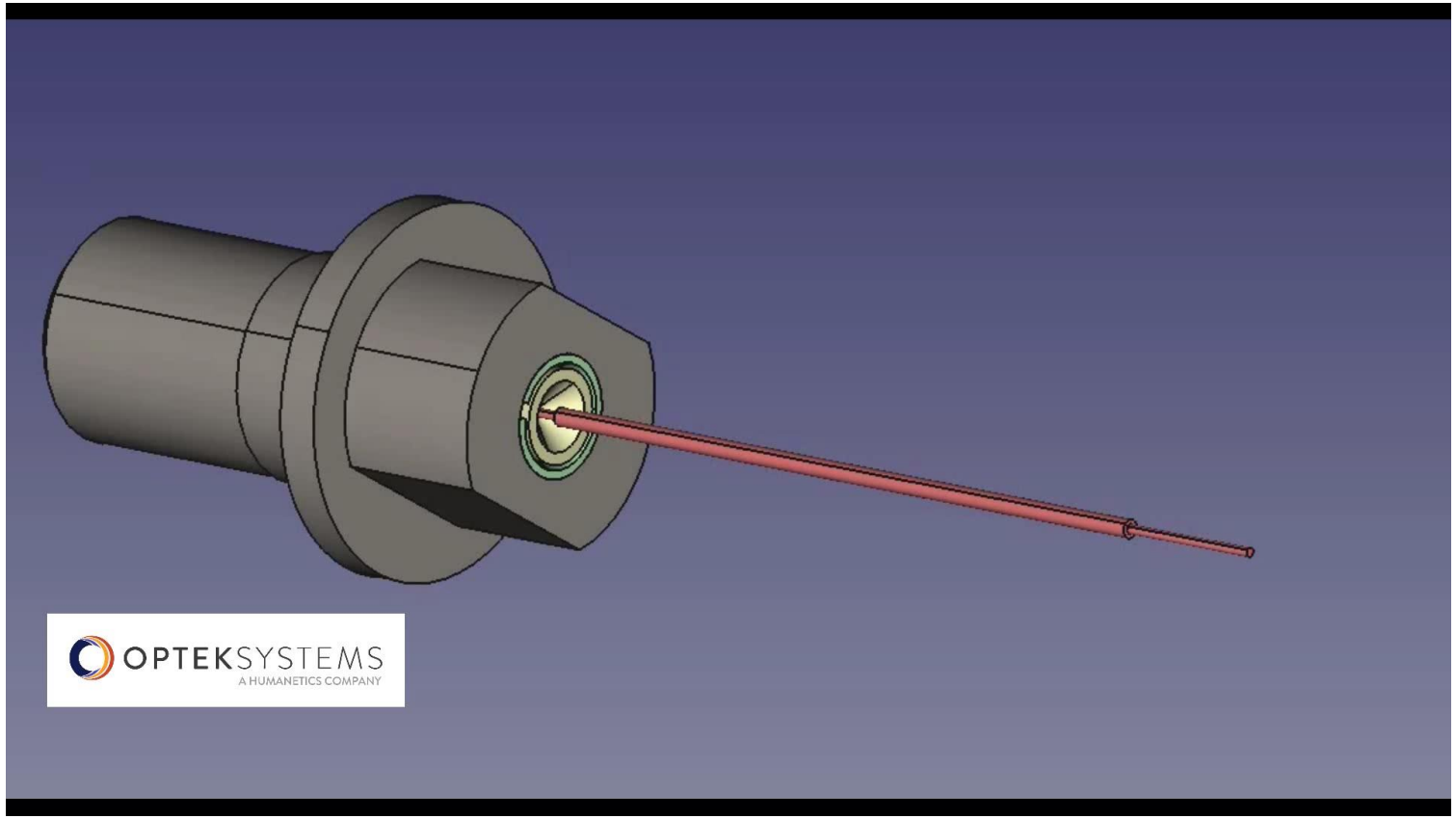
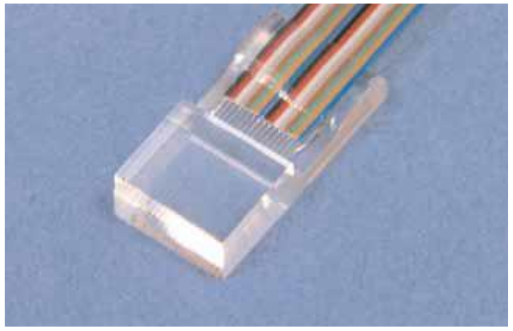
Complex Assemblies

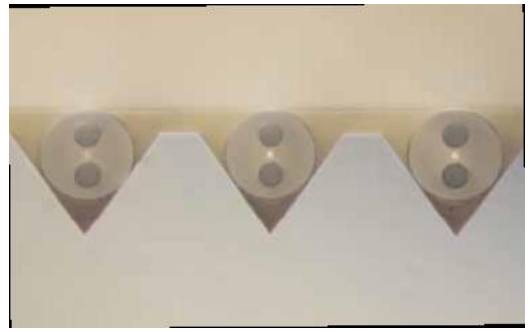


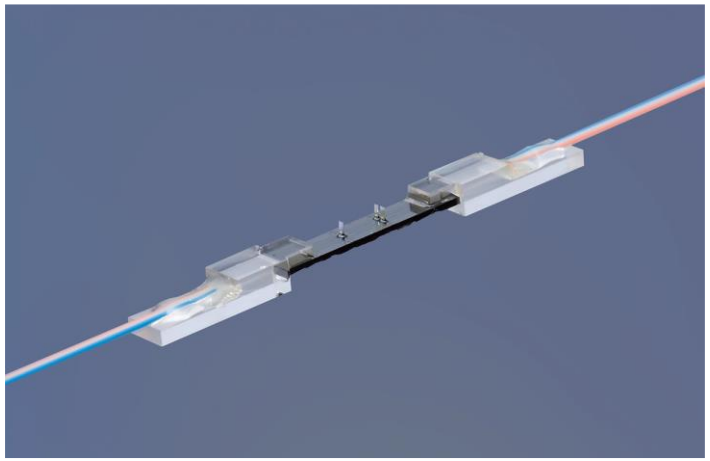
- Compact to fit into pluggables
- Spot Size Converters
  - PIC coupling
- GRIN Assemblies
  - Collimators
  - Isolators

Direct Connection

- V-Groove Assembly
- Waveguides & PIC's
- Lensed Connectors & Arrays







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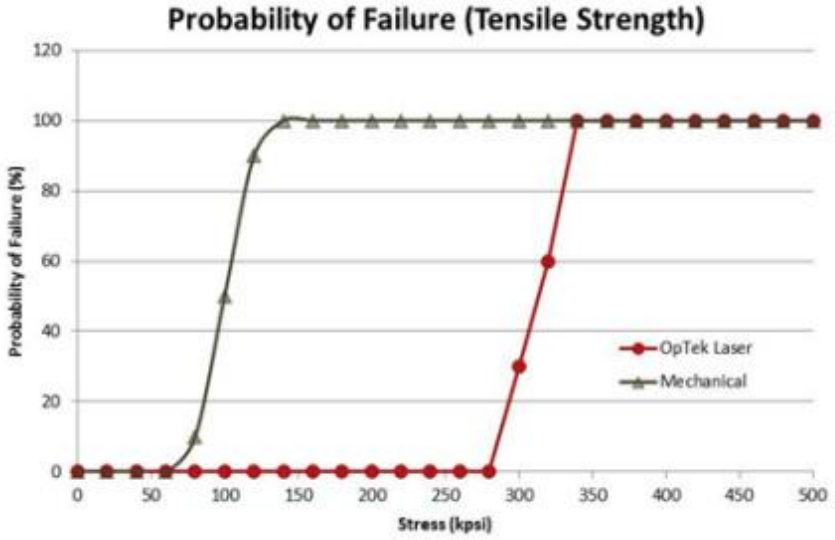
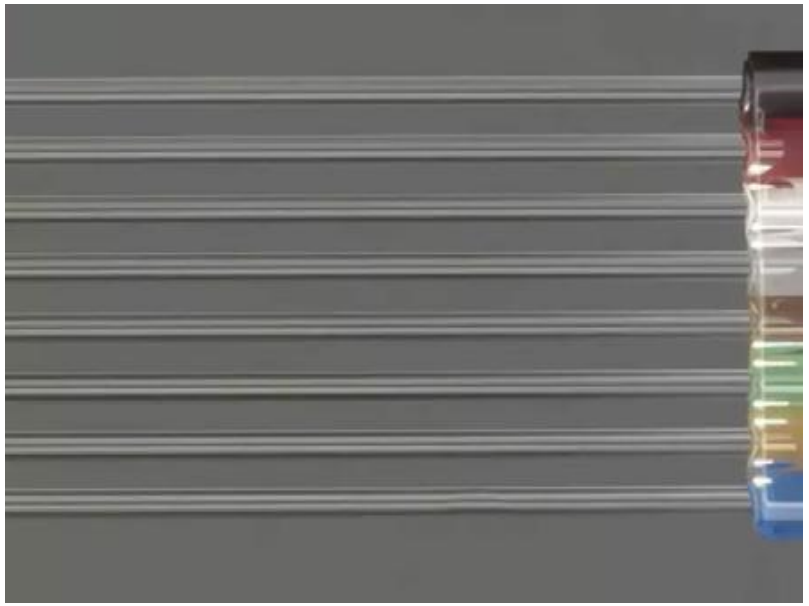
Buffer Stripping

Offering Systems for Simplex and Ribbon

- Rapid, non-contact processing
- Accurate and repeatable feature positioning
- Eco-friendly manufacturing (chemical free)
- Improve performance, increase yield, reduce manufacturing costs
- Reliability, the elimination of blades and, consequently, glass abrasions make this an ideal process for ultra-high reliability (UHR) applications
- Accurate and repeatable strip length with clean and well-defined shoulder
- High-throughput – less than 1 minute/fiber





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LS1500

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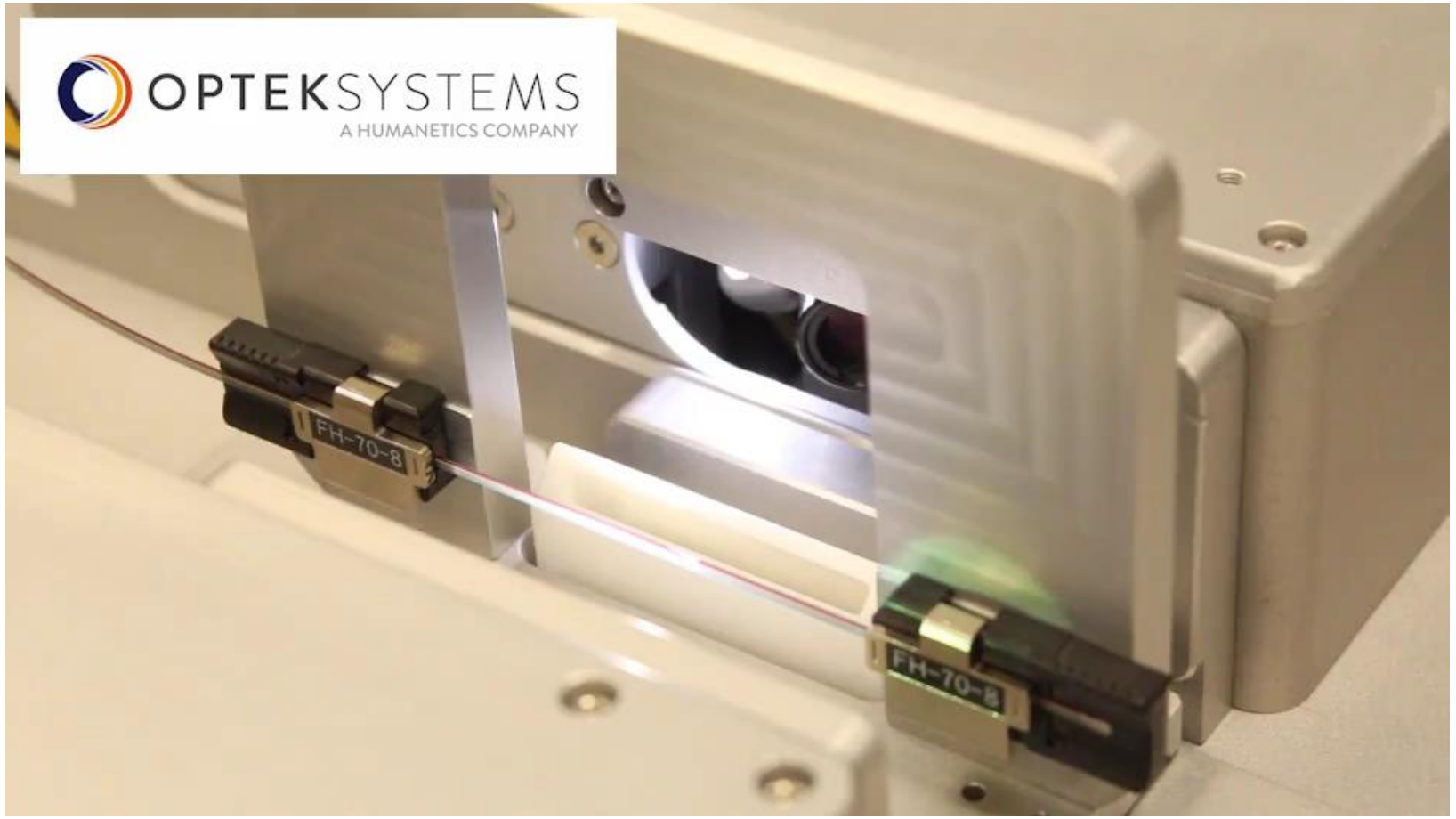

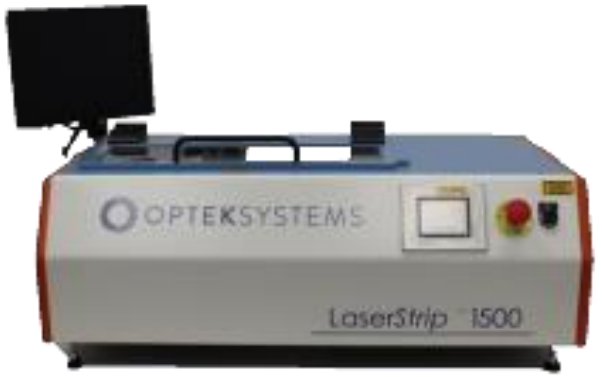

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Appendix

OpTek Systems

Formed in 2000 OpTek Systems is a laser micro-machining system integrator offering process development, bespoke tool design and integration as well as contract manufacturing services.

Standard products include the Laser Cleave product line focused on volume processing of fibre optics.

Developed in the 1990's and supplied to many blue chip companies around the globe, Laser Cleave is an enabling technology used in applications from pump laser diodes to field installable optical connectors. At the forefront of connector cleave technology Optek offers solutions for new technologies such as MXC, Thunderbolt and optical USB.

MATERIALS PROCESSING

Mike Osborne

Glass machining leaps into the 21st Century

Laser-based machining systems are bringing routine production to an area previously characterized by a craftsman's skill. New and complex glass geometries are opening exciting applications for a well-characterized and inexpensive material.

Cutting, drilling, and shaping of glass, quartz, and related materials has traditionally been achieved by skilled individuals using cleaving, grinding, polishing, or hot blowing techniques. Precision laser-based machining systems are now providing a fast, ... thermal conductivity, high temperature compatibility, excellent electrical insulation, and high optical transparency at a relatively low cost, all of which make it the material of choice in applications from windows to test tubes, optical fibers to attic insulation, and headlamp bulbs to furnace baffles.

Long-established methods exist for producing the raw material in the basic geometric forms of rods (including fibers ...

FIGURE 1. Both asymmetric (wedge) lenses (right) can be laser machined on the 9-µm-c telecommunications fiber.

accurate, and reproducible alternative that allows glass and glass-like materials to be processed as an engineering material in a production environment.

Silicon dioxide, in its many familiar for of glass, silica, and quartz, represents one the most useful materials known to mani It provides a unique combination of high sile strength, excellent chemical resistance

MIKE OSBORNE is technical director at OpTek Systems, Abingdon, England; e-mail: mike.osborne@optek.co.uk.

S4 May 2004 www.laserfocusworld.com La

Advances open new applications

Although the use of lasers for materials processing represents, in total, the largest global market for nondiode lasers, the materials-pro-

cessing "market" is in reality a collection of diverse and often otherwise-unrelated applications.

This month's Opto-electronics World serves to highlight this diversity. Old meets new in the first article about machining glass with a laser, a tech-

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21st Century Fiber Cleaving

New automated laser cleaving systems improve fiber optic component manufacturing efficiency and yield.

By Stephen Lee, Coherent Photonics Group, Laser Division and Gideon Foster-Turner, OpTek Systems

The explosive growth of the fiber optic industry, caused by the proliferation of broadband telecommunications is placing increasing demands on all aspects of fiber optic technology. One area of fiber optic technology that has experienced almost no technological advances in the past fifteen years is fiber cleaving. Fiber cleaving is still a ...

Figure 1. Automated and fully integrated, CO_2 laser cleaving systems used to cleave, strip, polish and shape fibers produce far more repeatable results than mechanical cleavers, thereby increasing yield while lowering manufacturing costs.

Figure 2. Laser cleaving systems achieve an exceptionally high reproducibility in cleave angle.

Cleave quality is critical for ensuring low reflectance terminations and enabling optimum performance of fiber optic components and systems. Fiber cleaving is typically carried out by mechanical means that first put the fiber under tension, and then use a mechanical blade to initiate the cleave. Unfortunately, the skill and experience of an operator are critical to this process. Consequently, yield and throughput are highly operator-dependent, and manual labor increases manufacturing costs.

Poor cleaves can cause cracks and scratches on the end of the fiber, which adversely affects the optical performances. Cracks and scratches can sometimes be corrected by polishing, however polishing is time consuming and adds cost. Furthermore, in the case of ferrule configurations, cracks caused by a poor cleave can sometimes extend below the surface of the ferrule.

The low yield, rework, long production time and manual labor involved in conventional fiber cleaving add to the cost of fiber optic component manufacturing and these issues are magnified greatly as processes are scaled up for higher volumes. However, a new technology using CO_2 lasers has been developed that enables consistently high quality automated cleaving for high-volume production of fiber optic assemblies.

Sealed CO_2 Laser Advantage

Advances in technology have led to the development of compact, high-power sealed CO_2 lasers that are ideal for integration into small, automated fiber cleaving systems. Sealed CO_2 lasers offer the benefits of conventional CO_2 lasers (high power and fast material processing) in a much smaller, no-maintenance and cost-effective package.

Sealed CO_2 lasers differ from conventional flowing-gas lasers in several ways. Most importantly, sealed lasers feature slab-discharge technology, which permanently confines the lasing gas mixture between two rectangular plate electrodes. This gas mixture lasts for up to 25,000 hours of continuous operation and the laser head requires no regularly scheduled maintenance.

The slab-discharge design also results in a compact laser with a high frequency pulsed output. Pulsing gives additional control over how much and how fast energy is delivered for material processing. Leading CO_2 manufacturers design their sealed lasers to operate in a 50% ON/OFF mode that creates high peak power. High peak power is important because it removes material faster and the OFF time allows material cooling and minimizes the heat-affected zone (HAZ). Consequently, sealed CO_2 lasers are ideally suited for use in industrial applications such as fiber cleaving.

Laser Cleaving

Laser cleaving of optical fibers has several economic and quality advantages over manual cleaving, due to the nature of laser technology and modern computer-aided manufacturing techniques. These advantages include high-speed cleaving, better cleave-to-cleave reproducibility, higher yields, greater cleave-angle control, a laser polished finish, greater cleave per formance, and the ability to strip buffer (or epoxy) and cleave in one operation. Stripping windows to write gratings on fibers is also possible.

Many of the advantages of laser cleaving stem from the fact that lasers are non-contact manufacturing tools that do not wear out. Consequently, there is no change in cleave-quality over time due to tool wear and no ongoing replacement tooling costs. This lowers manufacturing costs and improves cleave-to-cleave reproducibility.

Modern laser cleaving systems are specifically designed for use in manufacturing environments. Consequently, they are fully integrated, turnkey systems configured either as stand-alone production tools (see Figure 1) or as modules for integration into the production line or cell. The result is a user-friendly "black box" into which fibers are inserted for automated cleaving and removed after the operation is complete. This approach eliminates variations due to operator skill and improves yields.

The stand-alone design requires the use of cassettes into which either single, duplex, ribbon or ferrule fiber configurations are loaded. Once the cassette is loaded, it is inserted into the machine, and after the operation is complete, the cassette is removed, emptied and reloaded. To improve the flexibility of the system in a manufacturing environment, the cassettes are engineered to handle all connector types.

Despite a high level of automation and integration, laser cleaving systems are specifically designed to occupy minimal manufacturing floor space (55.1 in. x 31.5 in. x 47.2 in. [1.4 m x 0.8

Fiber Cleaving

Automation is the key to reliable and economical high-volume production because it improves product quality, consistency, yield and throughput. The growth of the fiber optics industry demands that more manufacturing steps, such as fiber cleaving, be automated ... largely mechanical and non-automated manufacturing process where operator skill and experience are critical to the success of the final product. However, advances in laser technology have led to the development of high-throughput automated fiber cleaving systems that use carbon-dioxide (CO_2) lasers to cleave fibers. These systems are operator independent and provide consistent high-quality cleaves on simplex, duplex, ribbon and ferrule configurations.

FIBEROPTIC PRODUCT NEWS® • MAY 2002

Invited Paper

PRECISION LASER PROCESSING FOR MICRO ELECTRONICS AND FIBER OPTIC MANUFACTURING

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ABSTRACT

The application of laser based materials processing for precision micro scale manufacturing in the electronics and fiber optic industry is becoming increasingly widespread and accepted. This presentation will review latest laser technologies available and discuss the issues to be considered in choosing the most appropriate laser and processing parameters. High repetition rate, short duration pulsed lasers have improved rapidly in recent years in terms of both performance and reliability enabling flexible, cost effective processing of many material types including metal, silicon, plastic, ceramic and glass.

Demonstrating the relevance of laser micromachining, application examples where laser processing is in use for production will be presented, including miniaturization of surface mount capacitors by applying a laser technique for demetalization of tracks in the capacitor manufacturing process and high quality laser machining of fiber optics including stripping, cleaving and lensing, resulting in optical quality finishes without the need for traditional polishing. Applications include telecoms, biomedical and sensing.

OpTek Systems was formed in 2000 and provide fully integrated systems and sub contract services for laser processes. They are headquartered in the UK and are establishing a presence in North America through a laser processing facility in South Carolina and sales office in the North East.

Keywords: lasers, micromachining, capacitors, fiber optics, cleaving, lensing, stripping, optical connectors

1. INTRODUCTION

The need for extremely precise micron scale components and devices with high quality finishes and exacting tolerances is continuing to promote growth in the area of precision laser micromachining. Relevant applications exist in many and varied industries such as Biomedical, Medical Device, Micro Electronics, Photovoltaic, Automotive and numerous others where there is a need for miniaturization or use of new materials that are challenging or even impossible to ...

INVESTIGATION OF LASER SCRIBING TECHNIQUES TO IMPROVE THIN FILM SOLAR CELL MANUFACTURABILITY AND PERFORMANCE

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ABSTRACT

The application of laser based materials processing for precision micro scale manufacturing in the electronics and Semiconductor industry is widespread and accepted. With the explosive growth and need for enhanced manufacturing capacity in the solar industry, this capability is now being applied and refined for solar cell manufacturing. The motivation comes from a need for ongoing improvements in throughput, yield and cell performance.

This paper will review some of the latest laser technologies and techniques available and discuss the issues to be considered in choosing the most appropriate processing parameters. High repetition rate, short duration pulsed lasers have improved rapidly in recent years in terms of both performance and reliability enabling flexible, cost effective scribing and dicing of many material types including thin films, metals, silicon, plastics, ceramics and glass.

Demonstrating the relevance of laser techniques, application examples where laser processing is being transferred from other industries for solar cell production will be presented, including highly accurate material handling from the flat panel display industry and adaptation of a thin film capacitor laser process for flexible solar cells.

OpTek Systems design and provide fully integrated machines and sub-contract services for laser processes. They are located in the UK and North America.

INTRODUCTION

To promote and justify the use of solar energy there is an ongoing need to improve efficiency of photovoltaic cells. Another important aspect is the cost effectiveness, hence there is also great interest in reducing manufacturing costs.

OpTek Systems are a supplier of laser processing equipment to solar cell manufacturers. These are not limited to, but include crystalline silicon dicing and edge isolation, P1, P2, P3, P4 scribes and micro hole drilling. OpTek has been involved in a number of research and development type projects through to providing turnkey machines used for process optimization and full scale production. OpTek are not a manufacturer or supplier of solar cells, only the machine tools used in manufacturing.

Today, laser processing is already employed for a number of PV applications and accepted in production, some examples are listed in Table 1.

Application	Laser
Dicing of crystalline silicon	Scribe and break, through cuts, not limited to straight lines
Edge isolation crystalline silicon	High speed automated processing
Scribing of thin films on glass substrates	Narrow scribes, flexible, high speed
Scribing of thin films on flexible substrates	Narrow scribes, flexible, high speed and can be integrated onto R2R equipment

Table 1 – Laser processing in PV manufacturing

The crystalline silicon based laser processes could be described as more mature, reasonably well characterized and widely employed in production today.

In the area of thin film based solar cells, coincidently where the efficiency is not as high as crystalline silicon, there are numerous factors driving the use of laser Technology:

- Improving cell efficiency by better use of available real estate – Monolithic integration of cells into large-scale panels
- Improving yield and overall manufacturability of the cells – Leading to lower cost
- Implementation of alternative materials facilitating higher efficiencies. Examples include copper indium diselenide (CIS), copper indium gallium diselenide (CIGS) and cadmium telluride (CdTe)

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2000
OpTek founded by 3 engineers in Oxfordshire, England

2001
First ma… delivere…

2006 - 2007
OpTek Systems Inc. established in South Carolina, USA

2009


Tek China …ablished, Hong Kong, …ijing and Dongguan

2011
Queen's Award for Export Achievement

2012
Expansion of UK premises

2016
Second Queen's Award for Export Achievement

2017
Austin, Texas USA office opened

2018
Expansion of Dongguan, China facility

2019
OpTek joins the Humanetics group

HUMANETICS

Bridgepoint

2020
Opening of new facility in Boston, USA

OpTek Systems rebranded to reflect its joining of the Humanetics Group Family

2021
Opening of new UK premises

New Global Managing Director

Bruce Valentine

2022
HUMANETICS SENSORS

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2023
ZOZEN 中正国际认证 ZOZEN International Certification

China Receives ISO 19001:2015 Accreditation

Group Receives ISO 27001 Accreditation

DSA

Partners with DSA

LRQA

UK Receives ISO 14001:2015 Accreditation

2024
LRQA

UK Receives ISO 13485:2016 Accreditation

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INDUSTRIES

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ENERGY

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PHARMACEUTICAL

SATELLITE & SPACE

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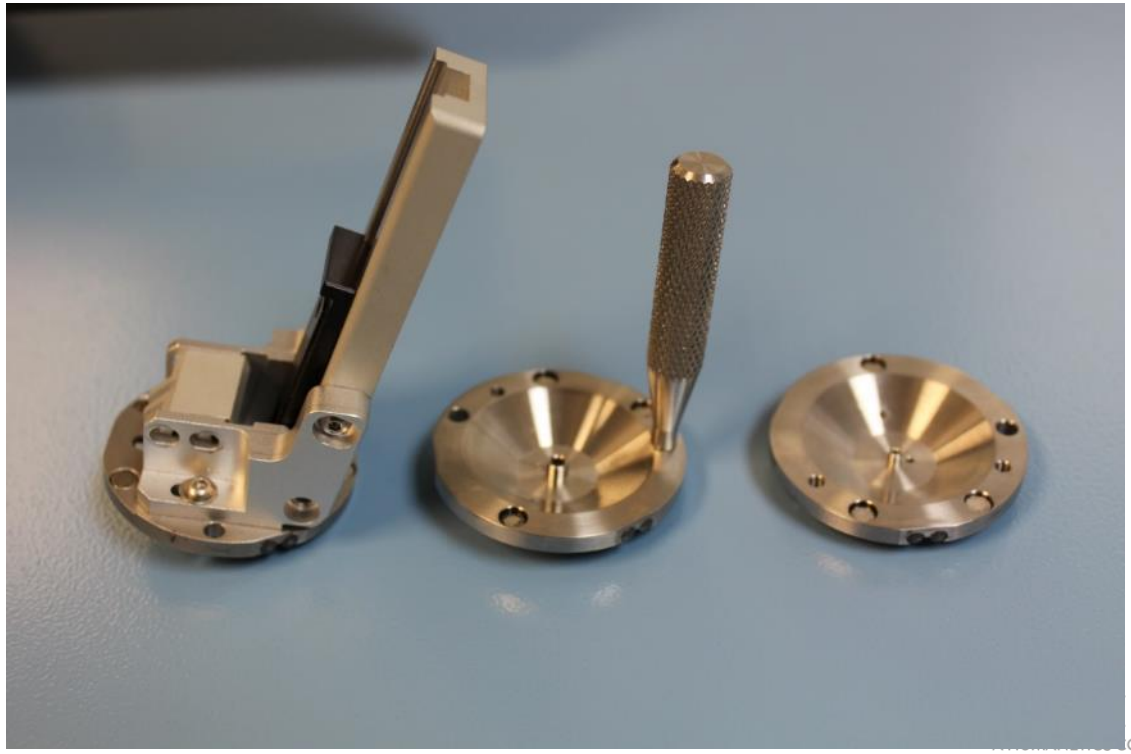
1500 Machine

- Single fiber (or ribbon) load
- Low multiples load (2, 3, 4, more)
- Ability to accommodate different parts through use of different cassettes
- Ferrule cleave
- Rounded cleave – Less dig into polishing film



500 Machine

- Small form factor
- Rapid, non-contact process
- Single Connector design
  (MTP or 2.5mm or 1.25mm)
- Ease of use
- Single and dual row (MT12, MT16, MT24, MT32)
- Cuts fiber and epoxy close to pedestal
- Accurate and repeatable cut off length
- Reduce number of polishing steps
- Reduce consumables and inventory
- Reduce hazardous polishing waste

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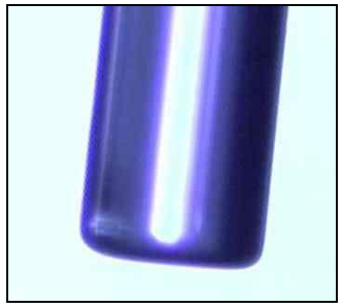
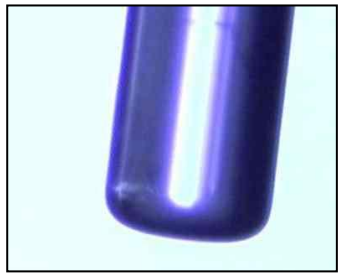
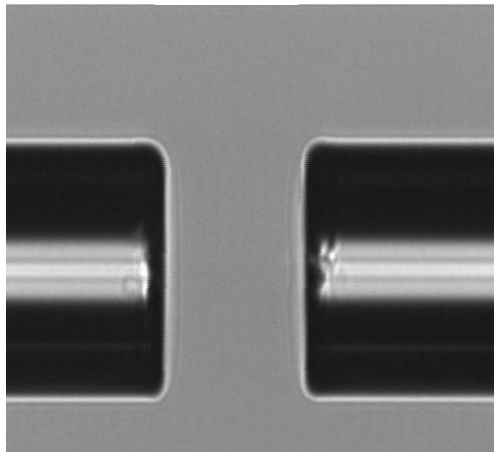
Laser Cleaves – What is a “flat” cleave?

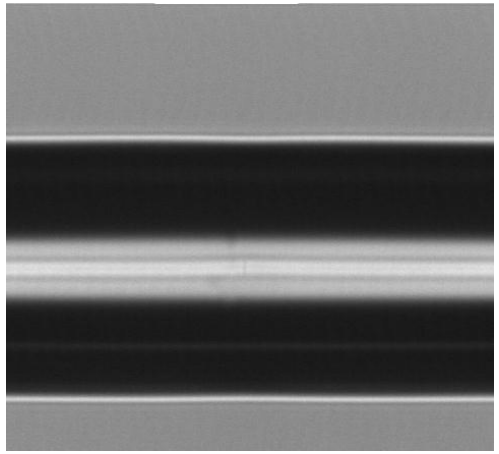
- Q – What is a flat cleave?
- A – It depends on the application

  - Square for fusion splice
  - Radiused for physical core contact
  - Rounded for insertion/robustness









- Low angle, square- cornered cleaves for fusion splicing
- Losses comparable to conventional cleaves
- Strength at least as good as conventional cleaves