Special optical fibers: production techniques and applications

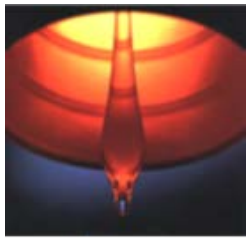
Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

Valerio Romano

Permanent collaboration between:

Bern University of Applied Sciences Institute ALPS

Research Group
Applied Fiber Technology



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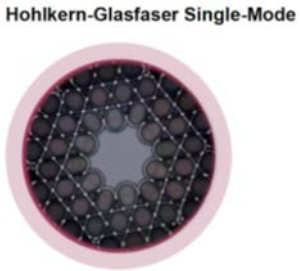
Institut für Angewandte Physik
Forschungsgruppe
Fasern und Faserlaser

Recall Swissphotonics Workshop in Burgdorf of Dec. 2015:

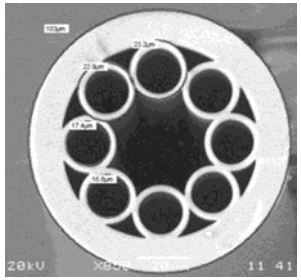
9.12.2015 Workshop:
Challenges for Swiss Amplifier and Delivery Fibers

- **Hollow core fibers**
  - Max. avg. Power?
  - Incoupling efficiency?
  - How robust?
  - Gas filling?
  - mJ at fs? J at ns?
  - Really flexible (for robot applications)
  - Polarisation?



Kagome fiber (produced by GLO-Photonics)

- **Amplifier fibers**
  - Exotic dopants to cover many wavelength ranges?
  - Broadband Fibers in the NIR (fs pulse amplification)?
  - Losses?
  - High power fibers (LMA)?
  - Microstructures? Multicore?



Pryamikov et al., Opt. Express **19** (2), p. 1441, (2011)

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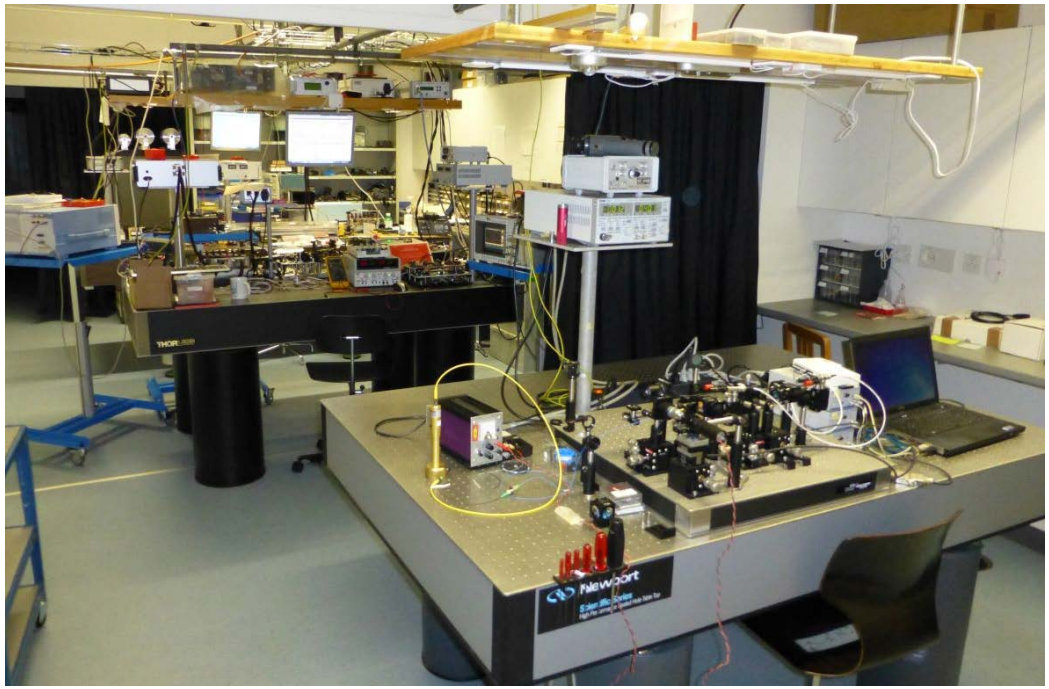
IAP Fiber Laboratory

research, application, characterization

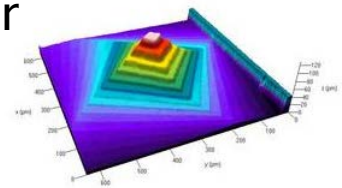


fabrication of specialty optical fibers

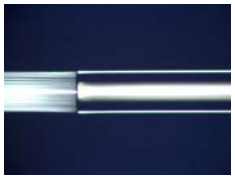
ALPS: Competences and Research Groups

Site Burgdorf:

- Laser Surface Engineering
  B. Neuenschwander



- Applied Fiber Technologies
  V. Romano



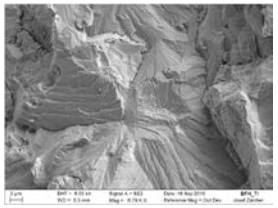
- Thin Films & Surfaces
  P. Schwaller

Site Biel:

- Materials Technologies & Heat Treatment
  S. Kleiner

- Material Analysis & Plasma Treatment
  M. Baak, Th. Nelis

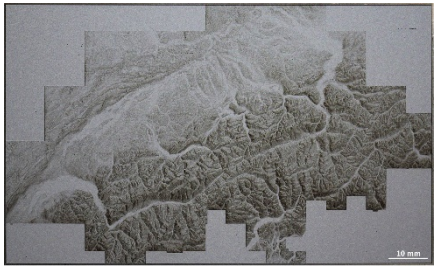
- Common Service Lab for Material and Surface Analysis
  J. Zürcher



Institute for Applied Laser, Photonics & Surface Technologies

ALPS (Burgdorf site)

Photonics Research Groups @ Site Burgdorf:

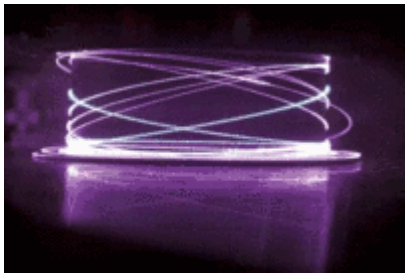


Laser Surface Engineering:

- Prof. Beat Neuenschwander
  - Prof. Dr. Guido Bucher
  - Dr. Marc Schmid
  - Dipl. Phys. Thorsten Kramer
  - MSc. Stefan Remund
  - MSc. Michalina Chaja
  - BSc. Martin Muralt
  - Yiming Zhang (Drd)
  - BSc. Markus Gafner

Mechanical Workshop:

- Peter Schütz
- Urs Hunziker



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  - Dr. G. Karametaxas
  - D. Kummer
  - MSc Ali El Sayed (Drd)
  - BSc Ch. Heger
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- MSc. Michalina Chaja
- BSc. Johannes Hörr
- BSc. Peter Cam
- David Kummer
- Adrian Ciccini

Materials Analysis:

- Josef Zürcher

Plus: MaterialsTechnology and Materials Analysis @ site in Biel

Applied Fiber Technology
Fields of activity

Fiber development

- Glass powder development for novel fibers
- Design and development of new fibers
- Analysis and development of fiber based delivery systems

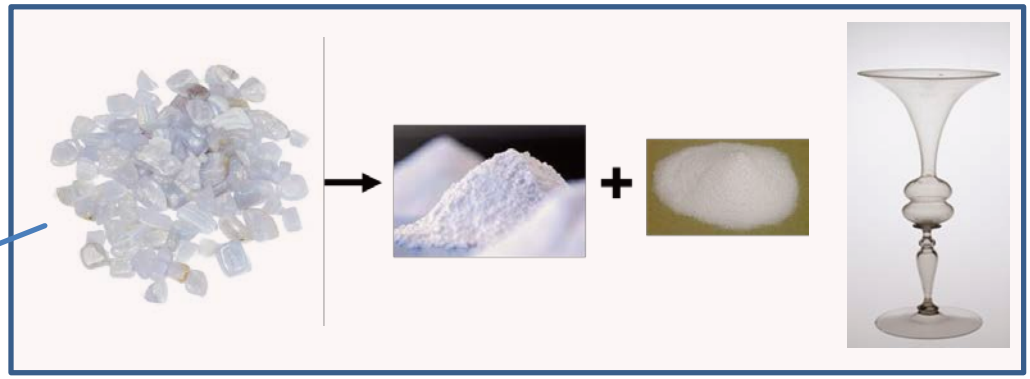
Application of high power, good beam quality, ruggedness

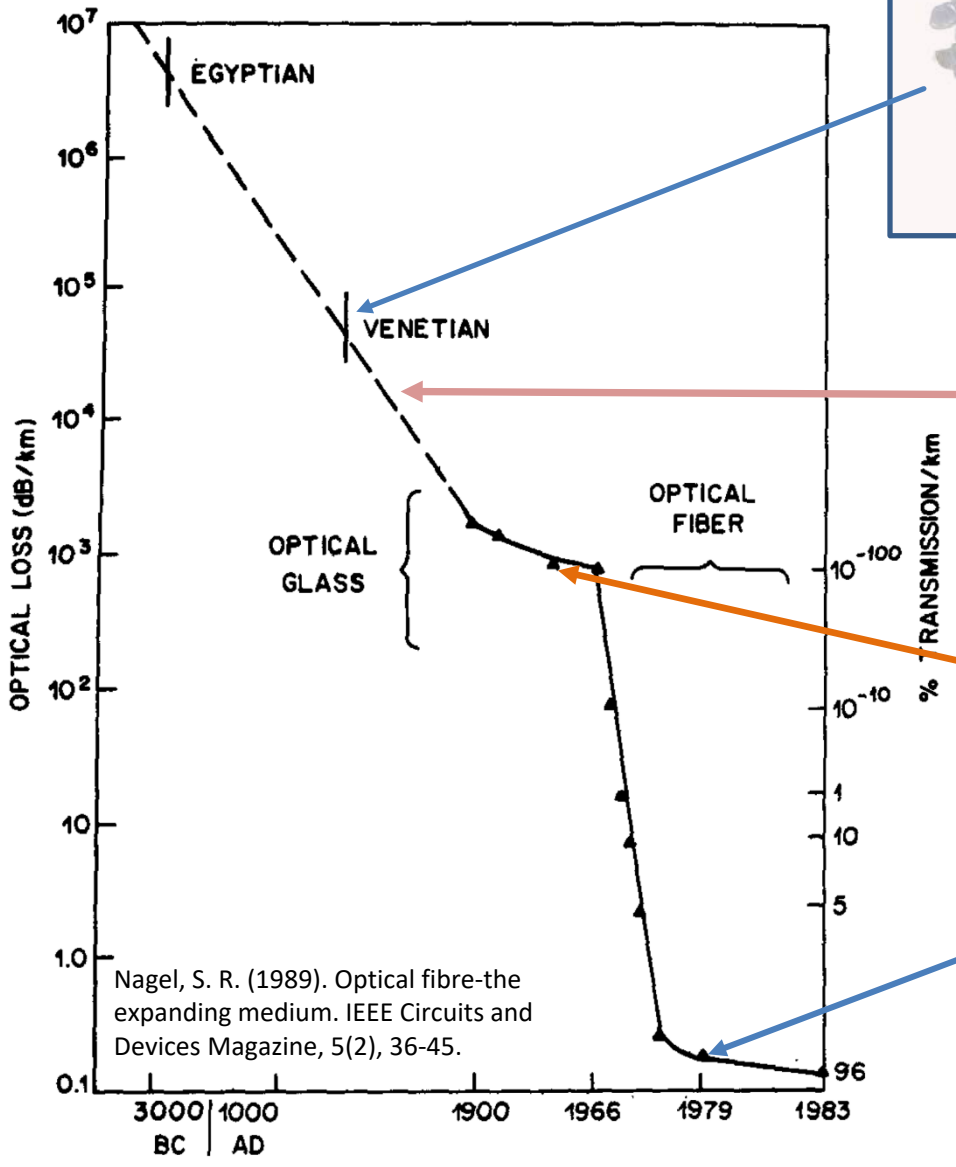
- Application of high power lasers in selective laser melting (SLM)
- Application in Laser cladding and Direct Metal Deposition (DMD
- Development of laser processes in additive manufacturing

Application of beam quality, high repetition rate, ultrshort pulses:

- Microprocessing (e.g. PV-thin films)
- Exploiting best beam quality and high repetition rates
- Pulselengths down to picoseconds and femtoseconds

Glass losses and production techniques





Nagel, S. R. (1989). Optical fibre-the expanding medium. IEEE Circuits and Devices Magazine, 5(2), 36-45.

1951-1957: Optical Fiber with cladding-core structure (US Patent 2,825,260

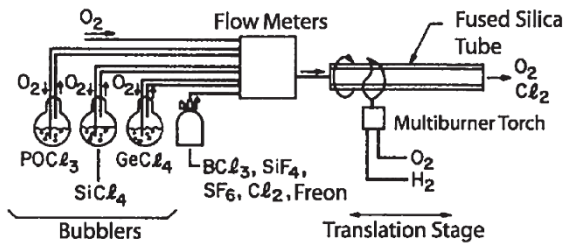
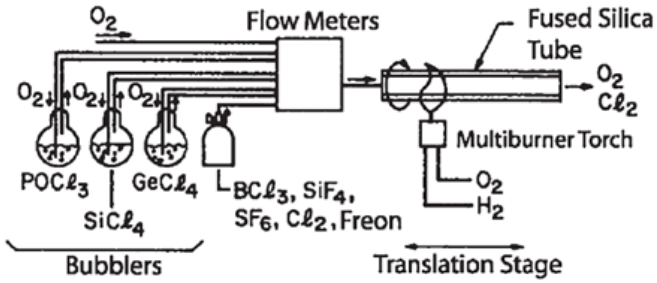


Figure 1.2 Schematic diagram of the MCVD process commonly used for fiber fabrication. (After Ref. [68]; © 1985 Elsevier.)

Vapor Deposition methods

(MCVD, VAD, OVD, PCVD, IMCVD)



(Nagel et al. IEEE JOURNAL OF QUANTUM ELECTRONICS, VOL. QE-18, NO. 4, April 1982

✓ highest purity, very low scattering losses (0.6dB/km@1100nm, 0.18dB/km@1550nm)
By the "filtering" effect of vapour pressure difference
Between precursors and impurities

not very versatile:

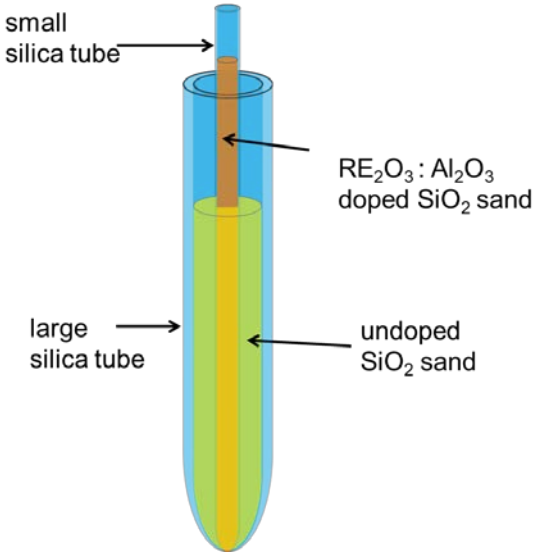
✗
- > difficult to fabricate large homogeneous cores
- > best suited for shapes with cylindrical symmetry
- > relatively big technical effort / cost
- > Doping at high concentrations is difficult

→ Special optical fiber production requires other methods

✗ Small amounts of material produced

Other production methods (silica based)

Repusil (IPHT Jena);
Background losses: 15dB/km@1μm wavelength



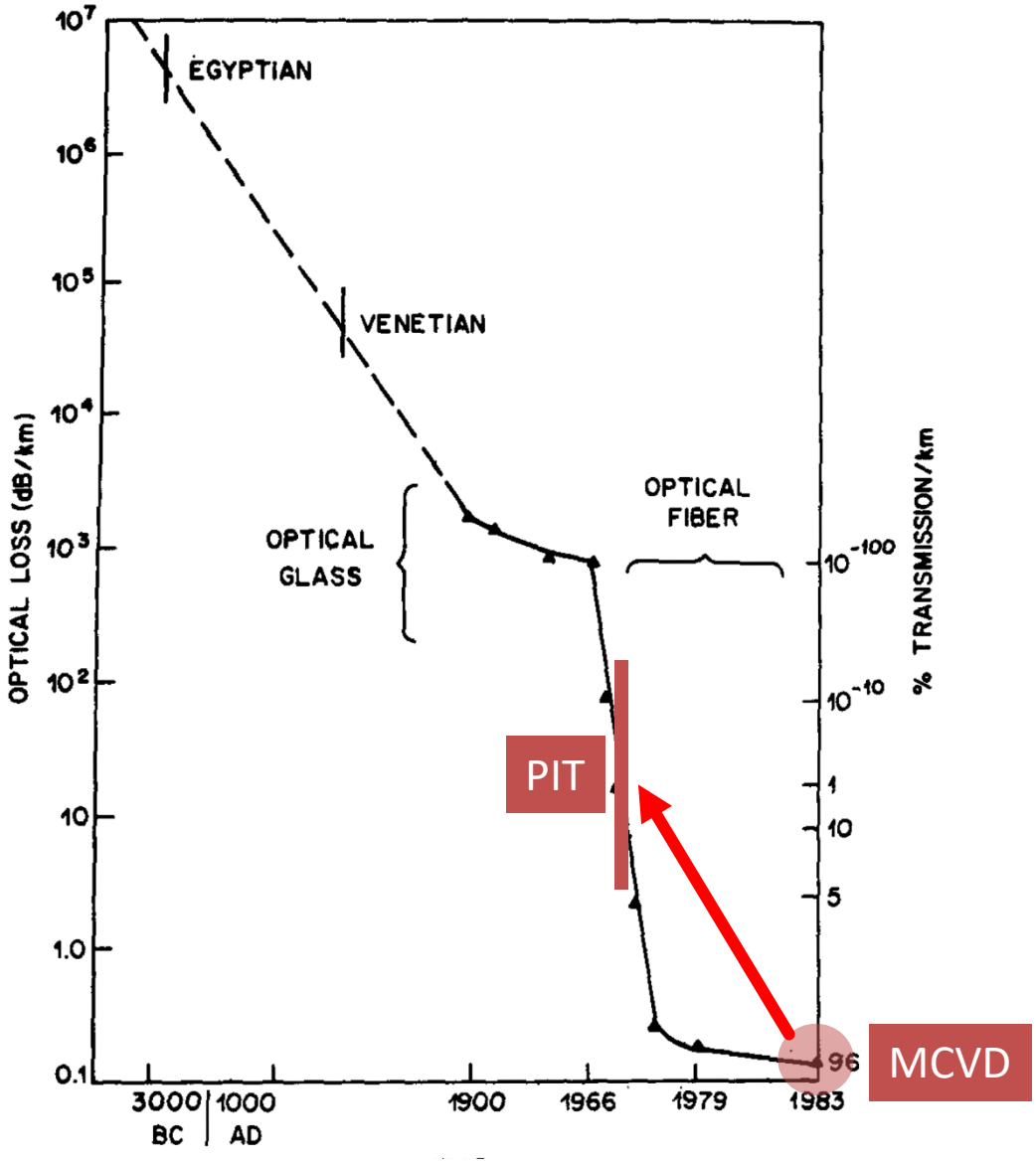
Powder-in-tube / granulate-in-tube methods

- Higher losses than Repusil but much faster (Rapid Fiber Prototyping)
- Glass can be produced in drawing tower or by previous vitrification

(IAP, BUAS, FORC, XLIM)

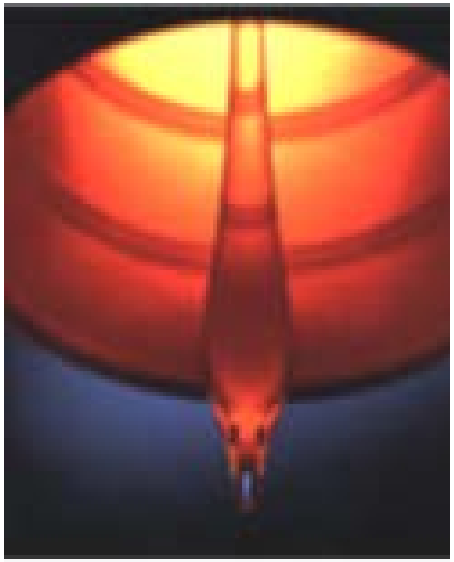
To re-gain more «freedom of shape and dopant» one goes back to powder technologies.

Back to powder: is it worth it?



- High dopant concentrations
- Processes are possible that allow to incorporate volatile materials
- Arbitrary shapes possible
- Arbitrary material compositions possible
- Multiple cores feasible
- Rapid production method
- Cost effective method

Do we produce glass?
Thermal quenching in a drawing tower



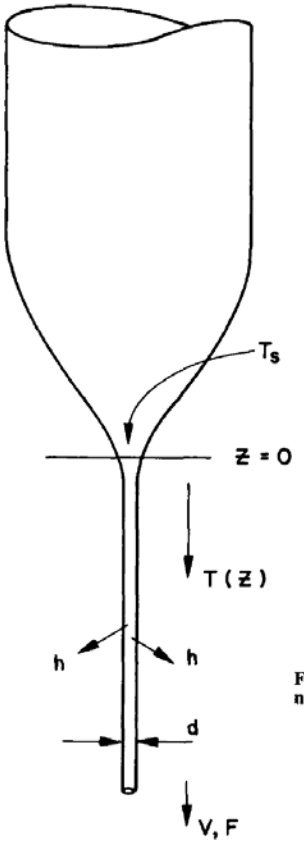


Fig. 1. Schematic of necked-down region in fiber drawing process.

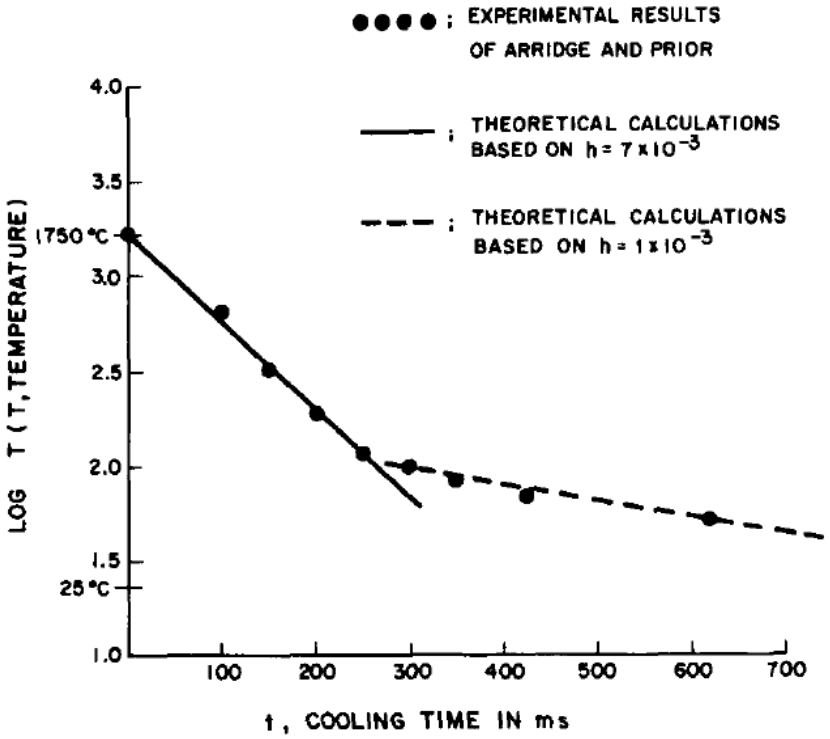


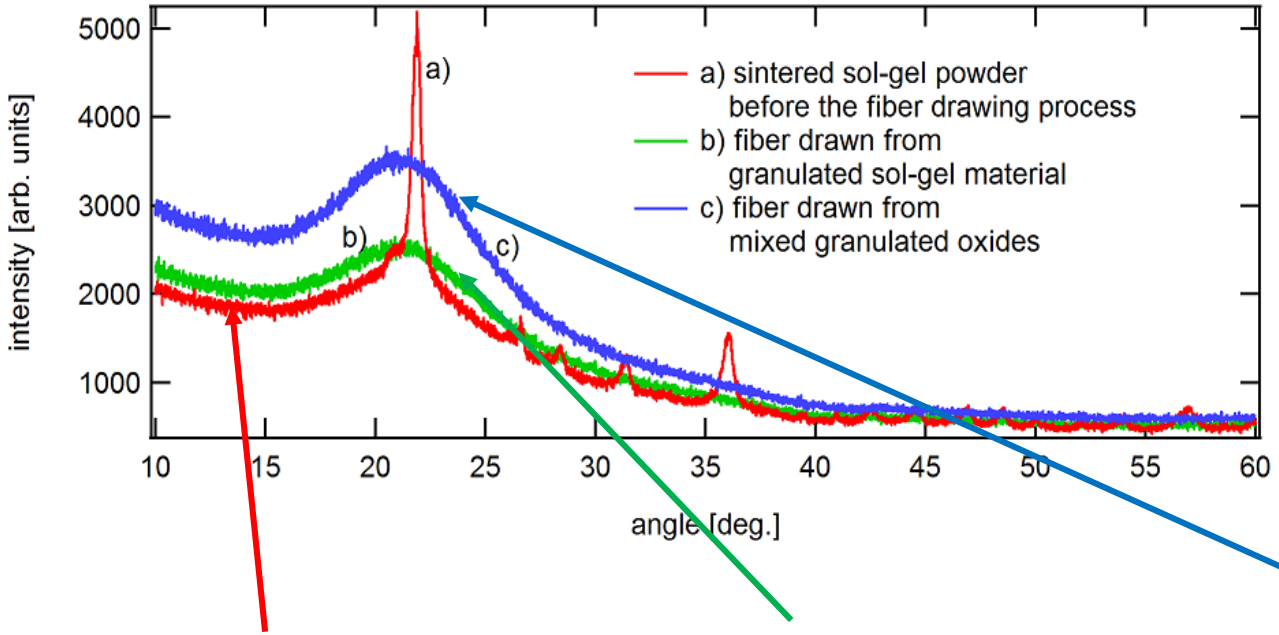
Fig. 2. Comparison of calculated and experimental cooling rates.

Paek, U. C., and C. R. Kurkjian. "Calculation of cooling rate and induced stresses in drawing of optical fibers." Journal of the American Ceramic Society 58.7-8 (1975): 330-335.

Cooling rates:
75'000 K/s in the first 10 ms;
5'500 K/s in the first 300ms;

Consequence of thermal quenching
In drawing tower

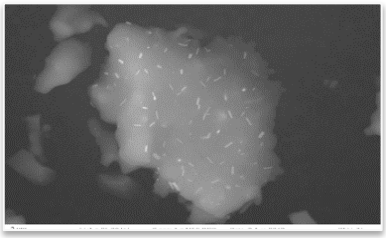
Test for Crystalline Silica : X-Ray Diffraction Measurement



Quenching the Sol-Gel material after heating at 1600

Crystalline material was amorphized after fiber drawing process

Crystalline

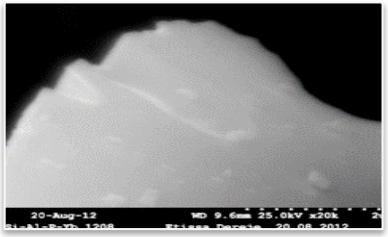


Before Drawing

Amorphous

Fiber from Sol-Gel Granulate

Amorphous



Fiber Directly from Granulates

Running Projects

Special fiber production:

- **Production of doped powder for fiber preform fabrication (National CTI project; BUAS / ReseaChem)**
- **Fiber preform fabrication with doped powders for High Power Ytterbium-doped Fiber Lasers (Large scale International project: IAP, BUAS, RESEACHEM, APRI, TFO)**
- **Highly Ytterbium-doped fibers for Photovoltaic applications (National CTI project; BUAS / Econimo Drive AG)**

Past and present contributors to this research

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reseachem
more than molecules!

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In cooperation with the CTI
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Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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Commission for Technology and Innovation CTI