

# A New Way to Utilize Atomic Layer Deposition – Case Study: Optical Fiber Manufacturing

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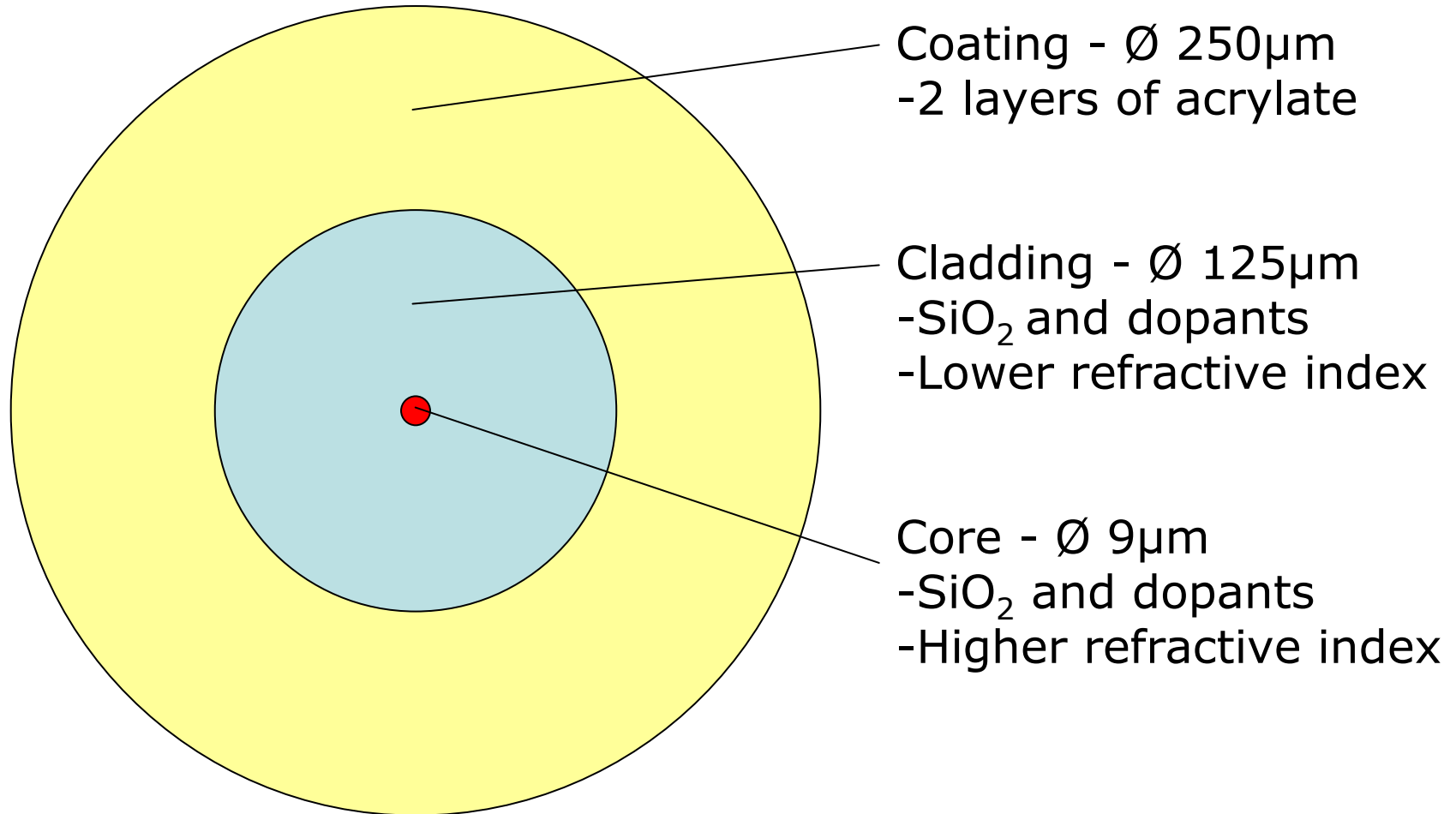
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## Contents

- ❑ Optical fiber
- ❑ Manufacturing of optical fibers
- ❑ Preform doping with ALD
- ❑ Potential of ALD in material preparation

## Standard Single-mode fiber



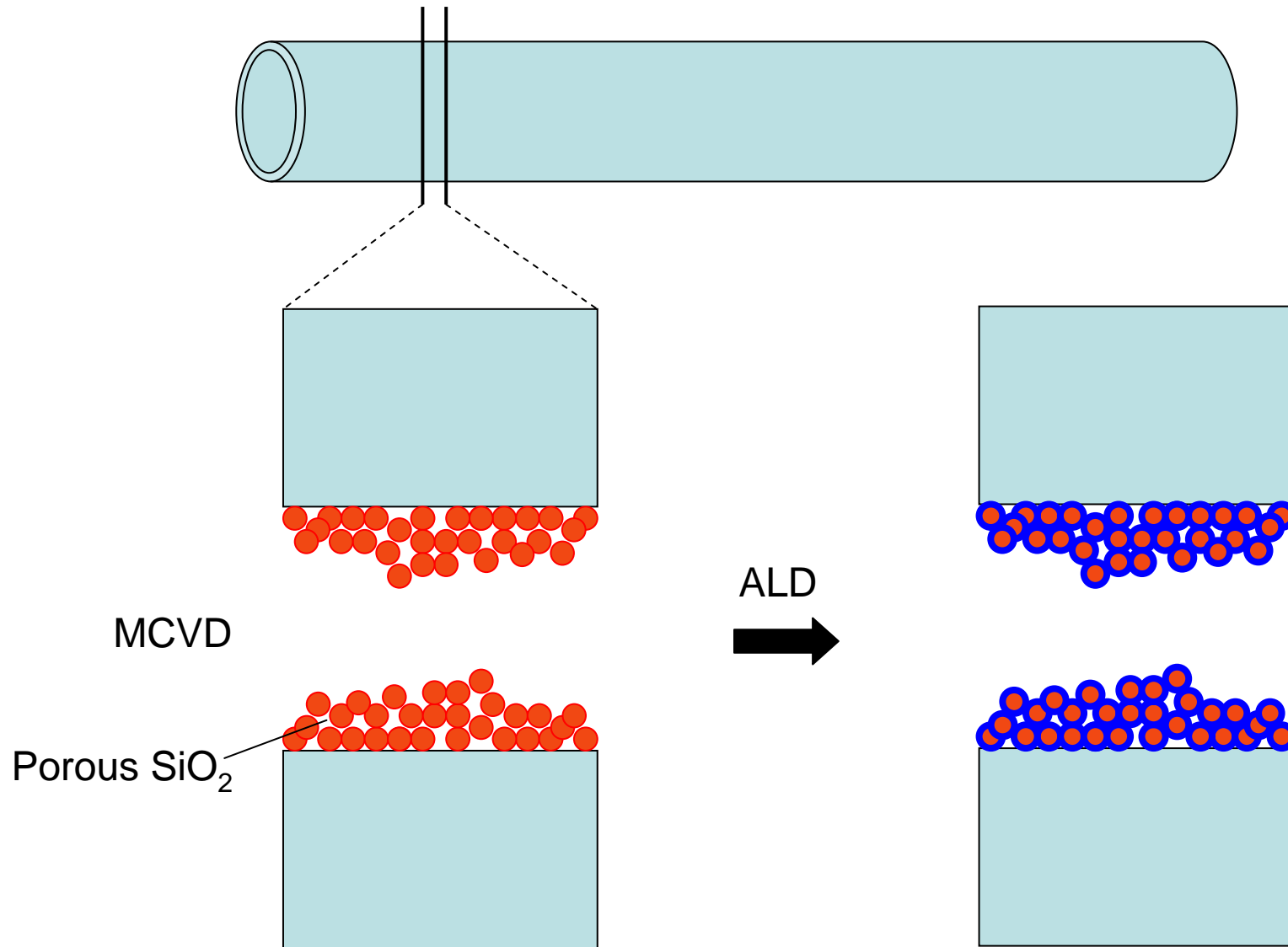
## Dopants used in typical optical fibers

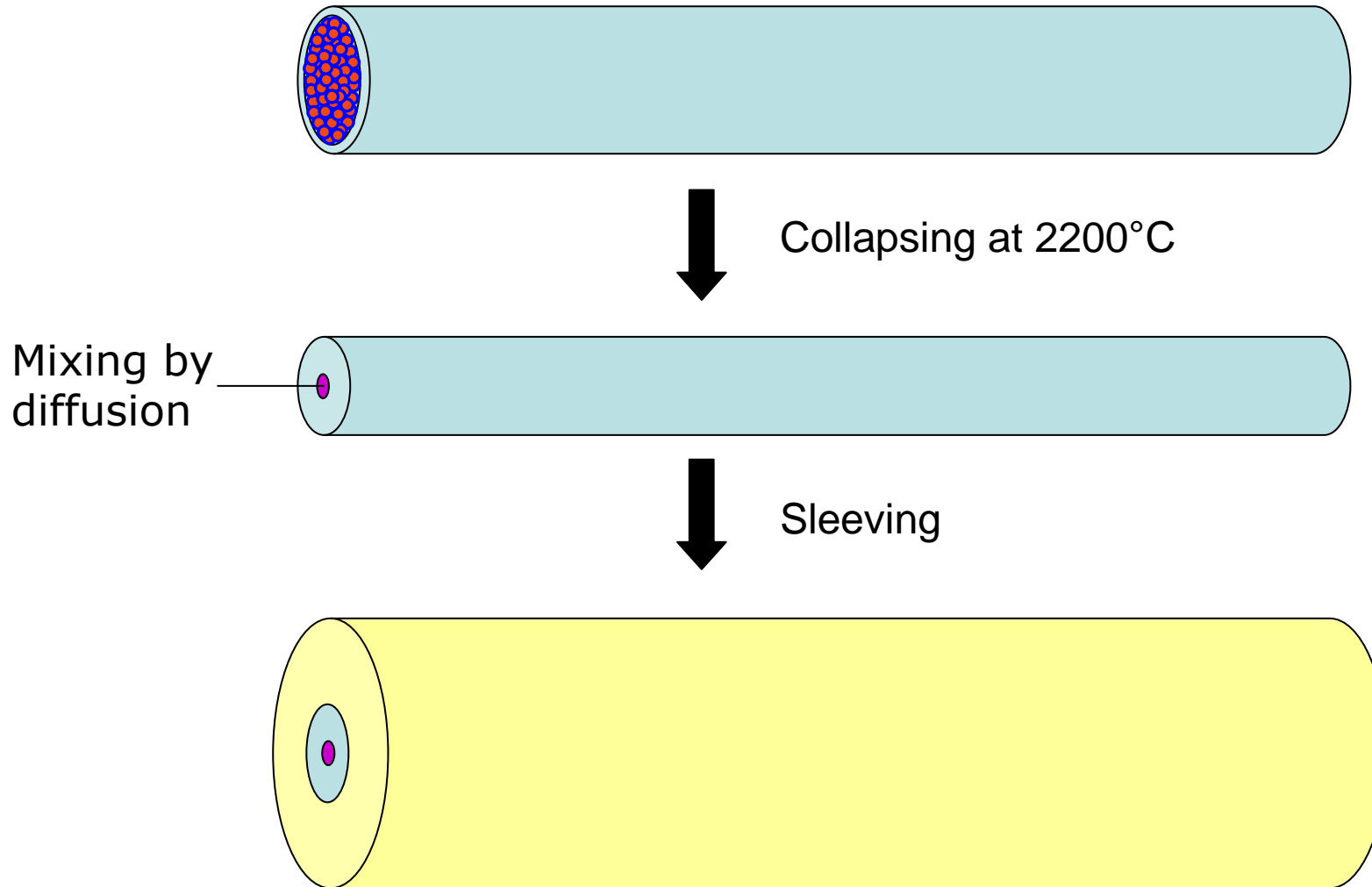
### Optical communication fibers

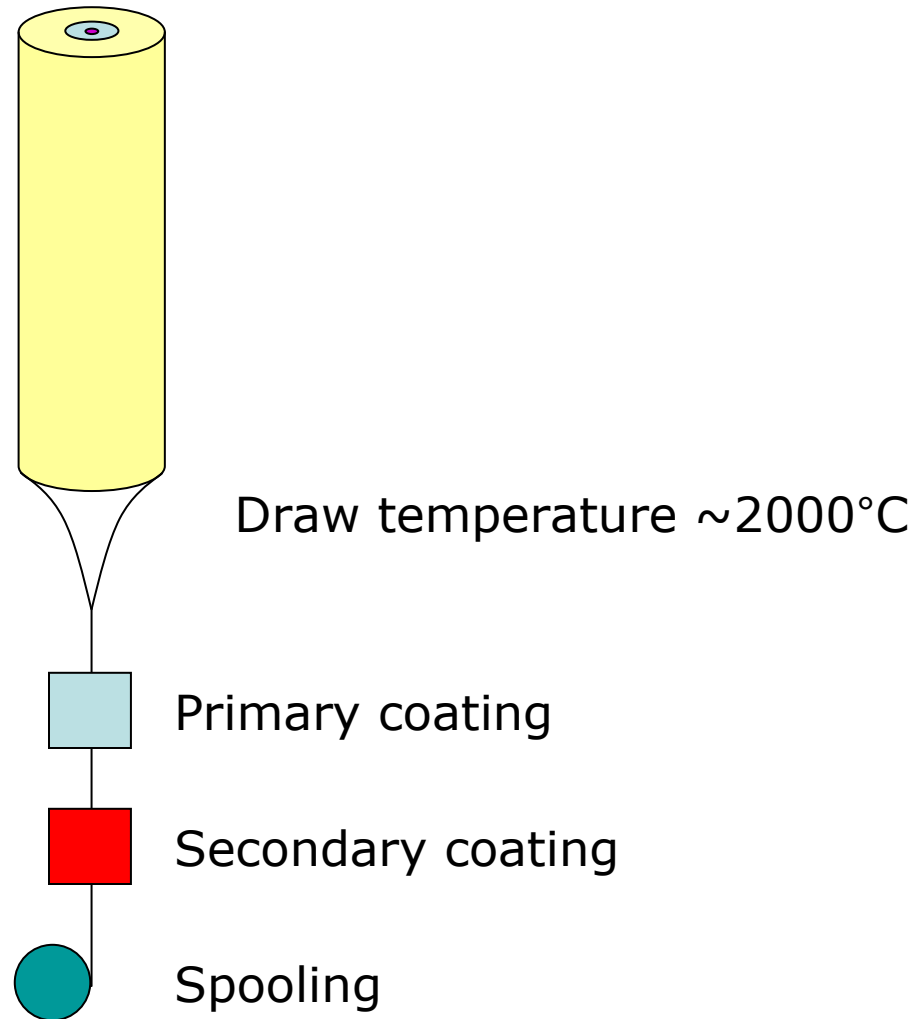
- $\text{GeO}_2$
- F

### Specialty fibers

- $\text{Al}_2\text{O}_3 / \text{Er}_2\text{O}_3$  optical amplifier fibers
- $\text{Al}_2\text{O}_3 / \text{Yb}_2\text{O}_3$  laser power guides







## Soot preform specification

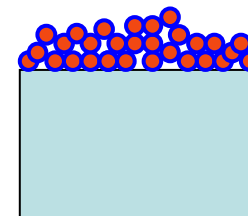
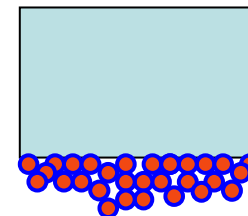
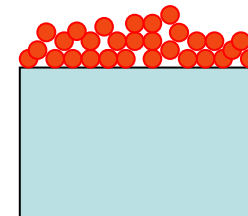
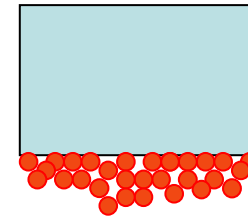
- ID 18 mm
- Soot thickness 27  $\mu\text{m}$
- Porosity 58 %
- Length 150 mm
- Doping  $\sim 20\%$   $\text{GeO}_2$  in  $\text{SiO}_2$

### □ $\text{Er}_2\text{O}_3$

- $\text{Er}(\text{thd})_3 + \text{O}_3$  at  $300^\circ\text{C}$
- 4 cycles
- Päiväsaari, J. *et al.*, *J. Alloys Compd.* **374** (2004) 124-128.

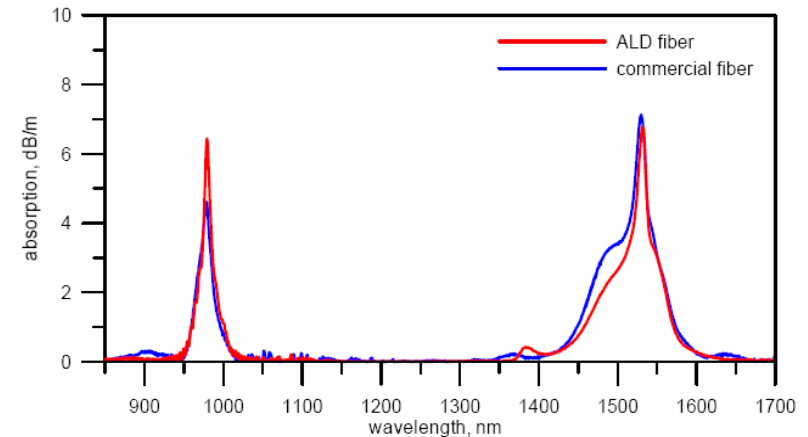
### □ $\text{Al}_2\text{O}_3$

- $\text{Al}(\text{CH}_3)_3 + \text{H}_2\text{O}$  at  $300^\circ\text{C}$
- 10 cycles



ALD doped fiber was characterized

- ❑ Spectral attenuation
- ❑ Erbium absorption
- ❑ Spectral photoluminescence
- ❑ Erbium excitation life-time



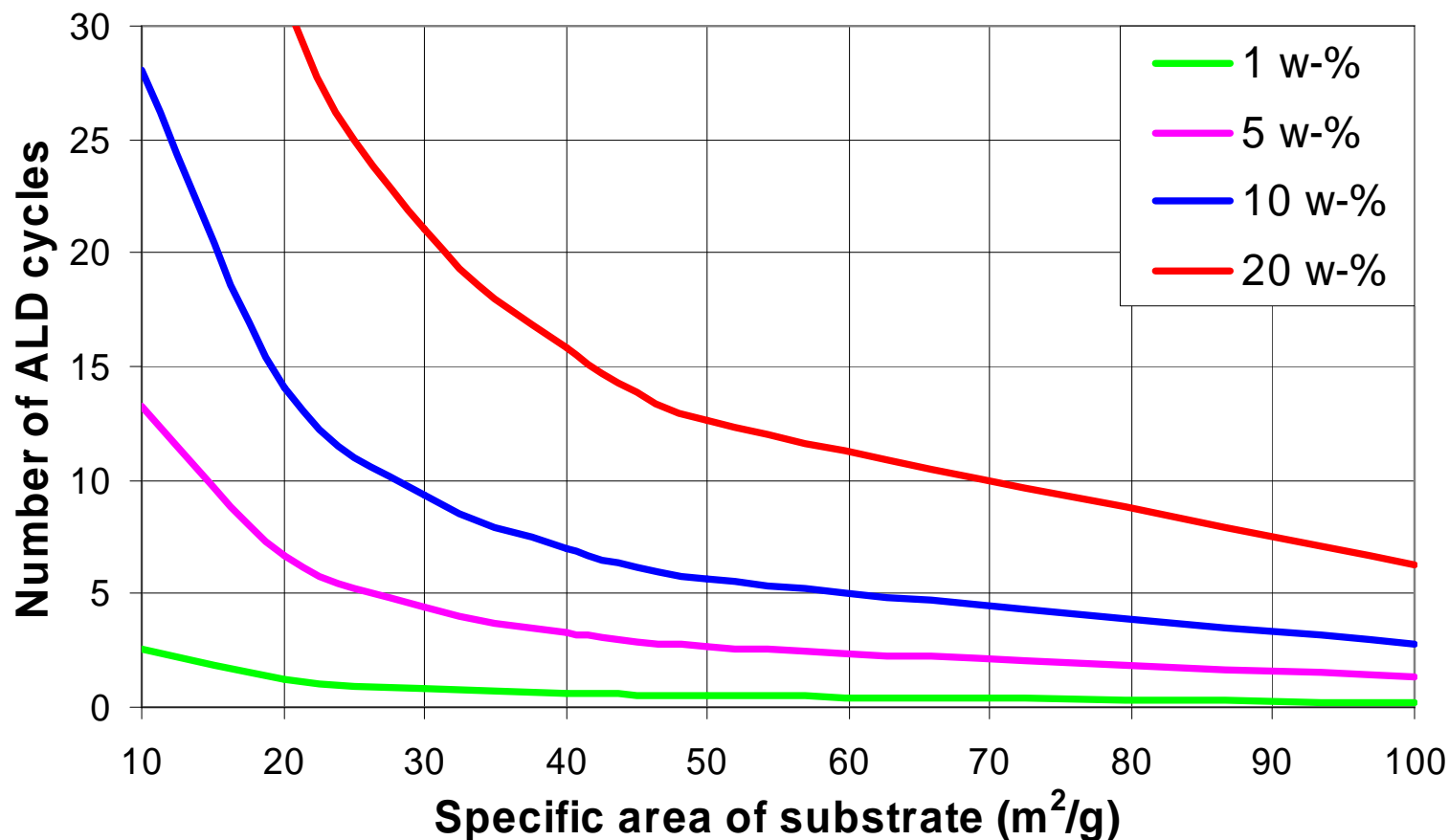
Fiber amplifier was prepared and demonstrated

- ❑ Spectral gain and noise figure

Results from the first test fiber were very close to values measured for commercial erbium doped fiber.

- ❑ ALD can be used for doping of optical fibers
- ❑ ALD offers superior control in doping

## Al<sub>2</sub>O<sub>3</sub> on porous SiO<sub>2</sub> substrate



Long history of ALD:

- ❑ Wide variety of materials available
- ❑ Plenty of experience with porous substrates

Numerous application fields, including:

- ❑ Fine ceramics
- ❑ Powder metallurgy: hard metals, magnets, composites
- ❑ Nanomaterials

Opportunities:

- ❑ New research areas
- ❑ New industrial applications

- ❑ ALD was used to deposit a thin film of dopant materials over a porous substrate
- ❑ Thin film was mixed to the matrix material by diffusion in following heat treatment phase
- ❑ Use of ALD in material doping was successfully demonstrated with optical fiber preforms
- ❑ A new way to utilize ALD in material preparation has been found