Fiber fuse behavior

veiled in its strong light emission

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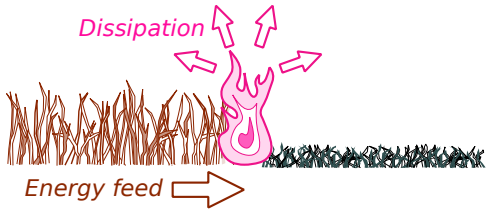
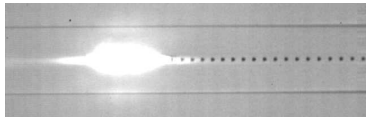
Introduction

Dissipative soliton

Grass fire:



Laser (>1W) ⟶
thru a single-mode fiber



$$SiO_2 \xrightarrow{\Delta} SiO_{2-x} + \frac{x}{2}O_2$$

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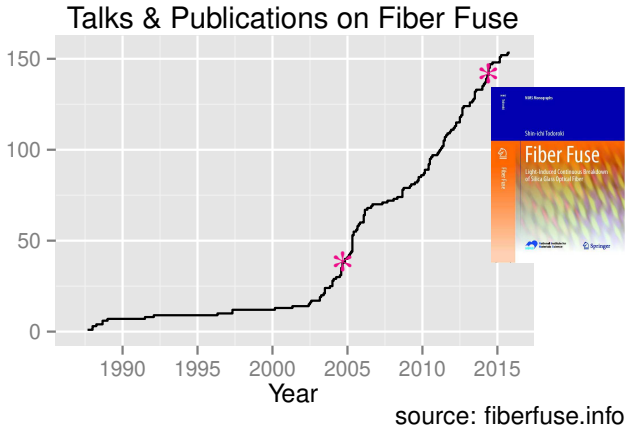
Introduction

What I've done.



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OVERVIEW

Fiber fuse behavior

Motivation

Why should we investigate it?

Termination

How it is trapped at termination devices?

Initiation

What is known about its initiation process?

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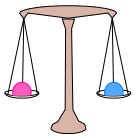
Motivation

Dilemma of silica glass fibers

Risk: high-power light manipulation

vs. **Expected capacity saturation**
in Optical communication systems



vs. **Required energy**
in Power-over-Fiber (PoF) applications

$\Longrightarrow$ Submarine sensors

$\Longrightarrow$ Ice sheet exploration

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Motivation

Commun. capacity saturation

D. J. Richardson, *Nature Photnics* (2013)

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Motivation

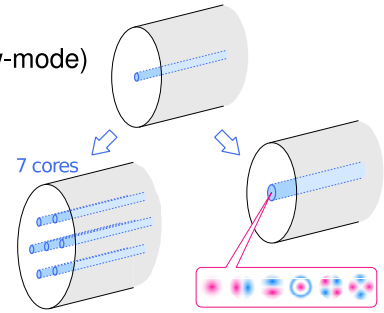
Space division multiplexing

- Capacity enhancement w/o power density increase

  $\Longrightarrow$ Multi-core

  $\Longrightarrow$ Multi-mode (Few-mode)

- Still caught
  in **the dilemma**



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OVERVIEW

Fiber fuse behavior

Motivation

Better risk management of high power-over-fiber apps.

Termination

How it is trapped at termination devices?

Initiation

What is known about its initiation process?

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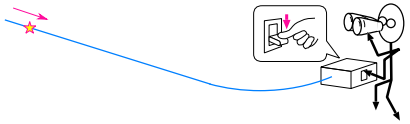
Termination

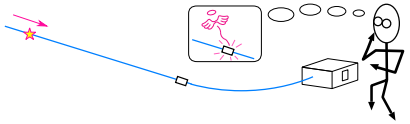
Proposed technologies

for single-mode fibers in opt. commun.

- Remote sensing → Power shutdown



- Local trap → Excess dissipation



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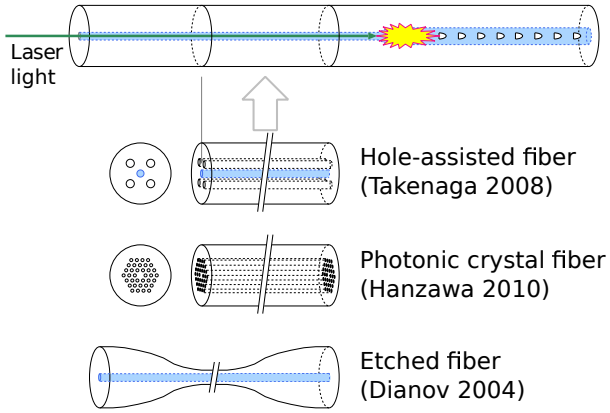
Termination

(1) Pressure leakage



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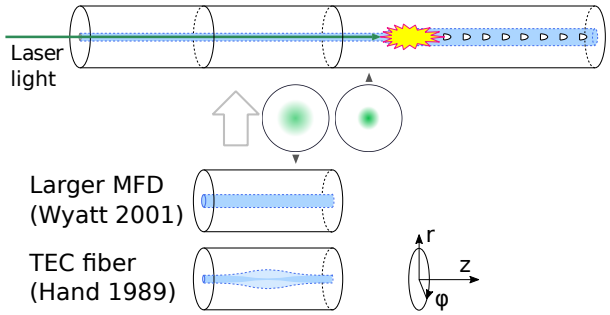
Termination

(2) Mode field expansion



Why it is trapped in spite of $\frac{d}{dz}\int \boldsymbol{I}(\boldsymbol{r},\boldsymbol{\phi})dS = \text{const.}$?

$\Longrightarrow$ Need to know its propagation behavior

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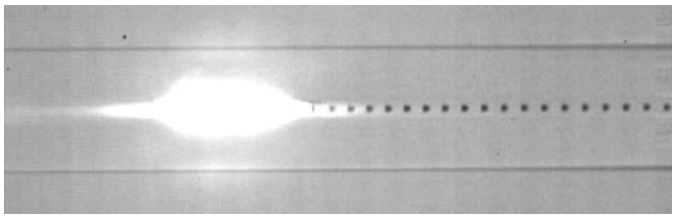
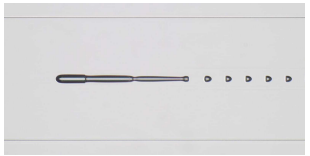
Propagation

The key is left behind it.



⇓ Power shutdown



Periodic voids

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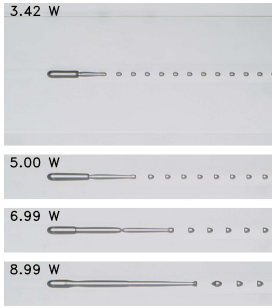
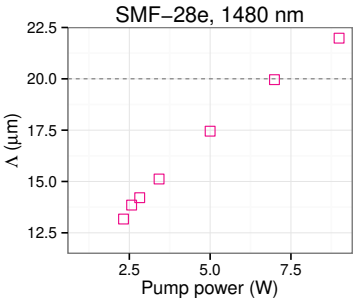
Propagation

Void interval vs. Pump power





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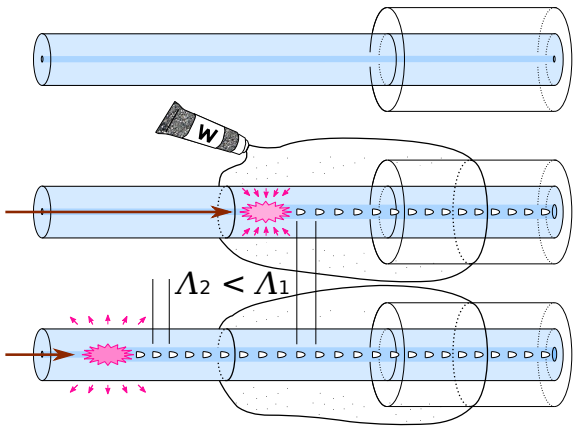
Propagation

Self-pumping effect



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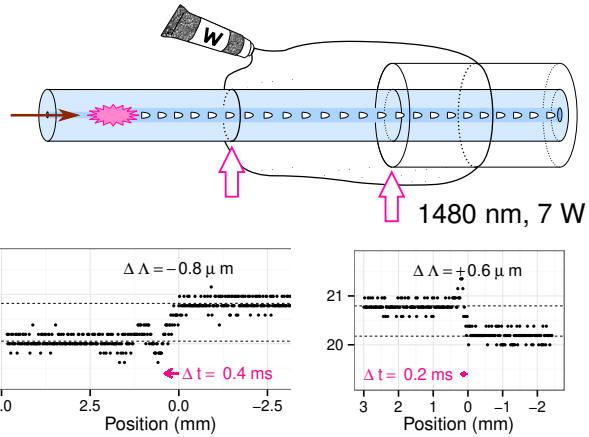
Propagation

Response delay due to viscosity



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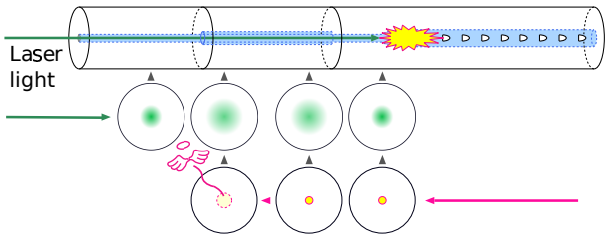
Termination

The mechanism



Delayed expansion

⇓

Termination ⇐ Power feed exhaustion

$$\frac{d}{dt}\int \boldsymbol{I}(\boldsymbol{r}, \boldsymbol{z_0})\boldsymbol{A}(\boldsymbol{r}, \boldsymbol{z_0})dS < 0$$

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OVERVIEW

Fiber fuse behavior

Motivation

Better risk management of high power-over-fiber apps.

Termination

Viscous silica melt causes a delay in response.

Initiation

What is known about its initiation process?

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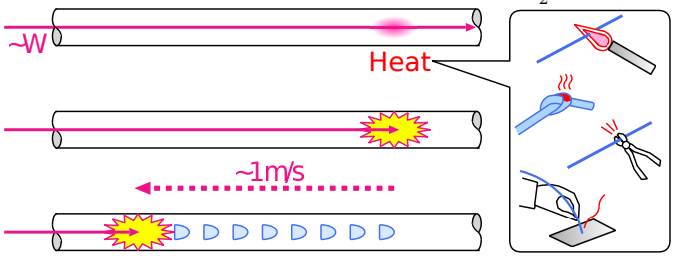
Initiation

Quantitative evaluation is very hard

$$SiO_2 \xrightarrow{\Delta} SiO_{2-x} + \frac{x}{2}O_2$$



How much is the minimum laser power for initiation?

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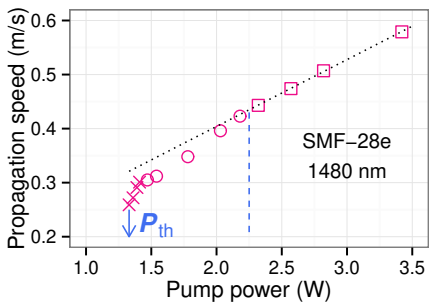
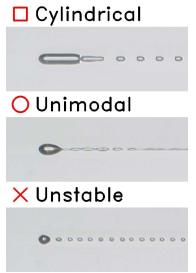
Initiation

An alternative criteria

The minimum laser power for propagation





No info about initiation!

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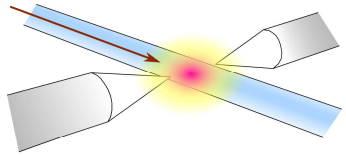
Initiation

To quantify heat & time,

- Arc discharge in a fusion splicer

Laser: 1.5 – 7 W



100%,
130%,
160% for 1 sec.

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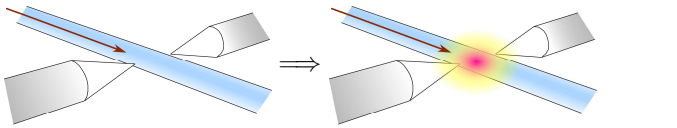
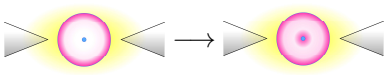
Initiation

Heating scheme



$$SiO_2 \xrightarrow{\Delta} SiO_{2-x} + \frac{x}{2}O_2$$



10 trials

$\Longrightarrow$ No change / Deformation / Initiation / Melt down

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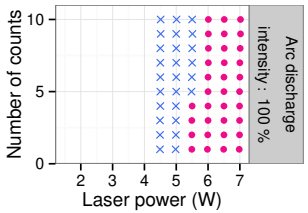
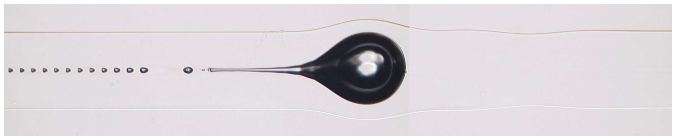
Initiation

Arc discharge: 100 %





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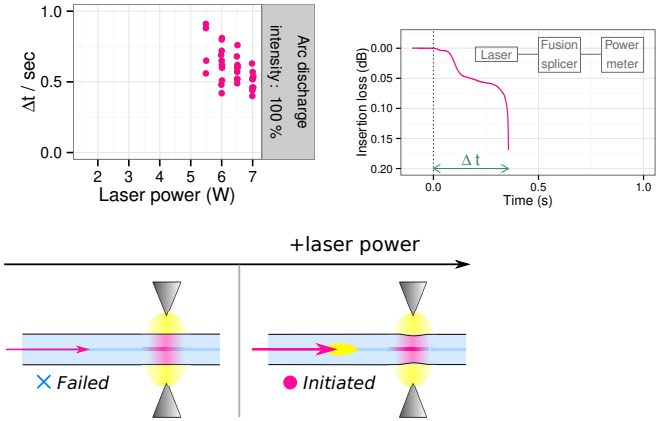
Initiation

Dacay time



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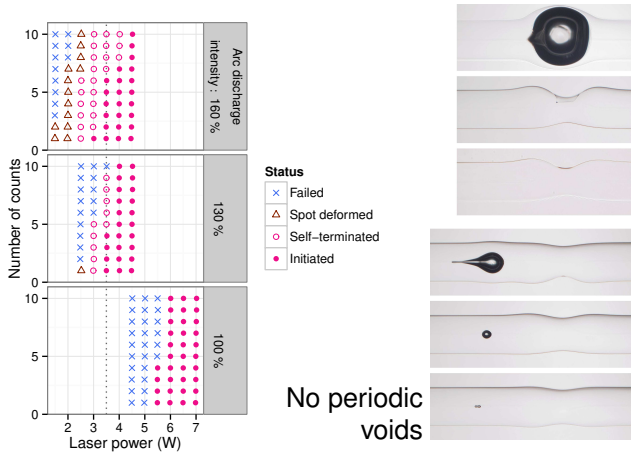
Initiation

Increasing arc discharge



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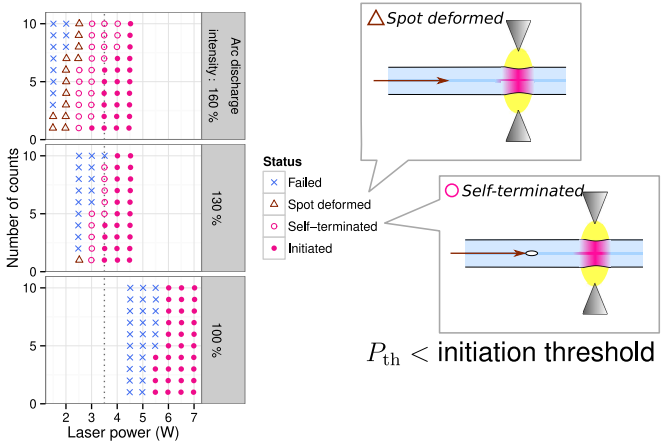
Initiation

The mechanism



$P_{\mathrm{th}} <$ initiation threshold

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SUMMARY

Fiber fuse behavior

Motivation

Better risk management of high power-over-fiber apps.

Termination

Viscous silica melt causes a delay in response.

Initiation

It requires more than threshold power for propagation.

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