

# Fiber Fuse: its Actions, Behaviors and Control methods

Shin-ichi TODOROKI

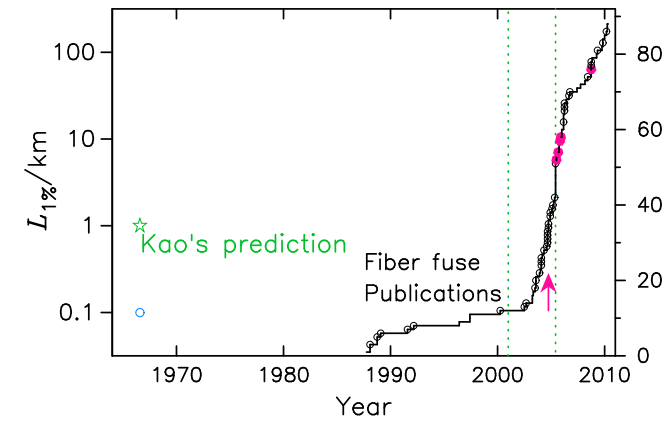
NIMS, Japan



Slide 1

## Introduction

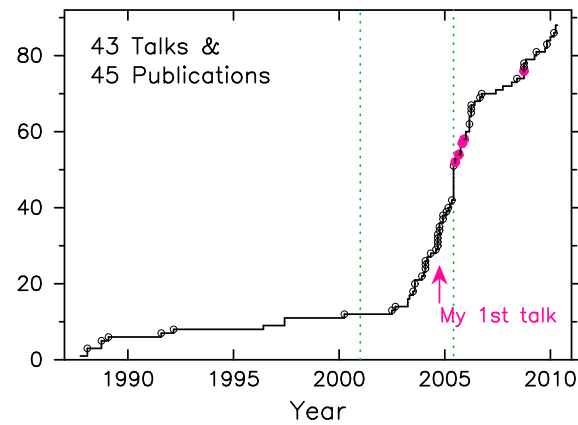
## A 2009 Nobelist's work (Physics)



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## Introduction

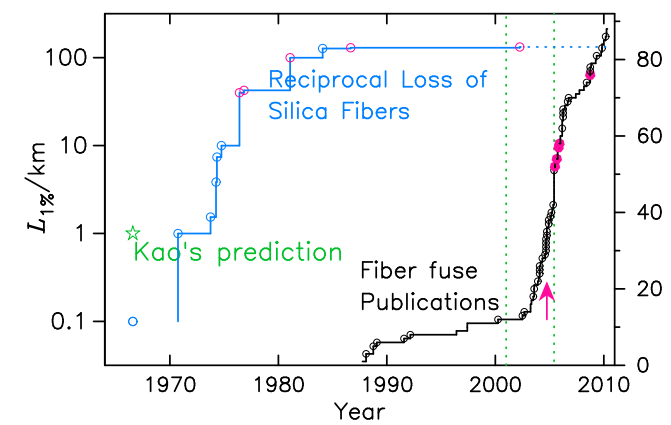
## Research papers on Fiber fuse



Slide 2

## Introduction

## Loss reduction of silica fibers



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## OVERVIEW

*Fiber Fuse: its Actions, Behaviors & Control methods*

### Behaviors

Why transparent fibers break down?

### Actions

What's happening in the spot?

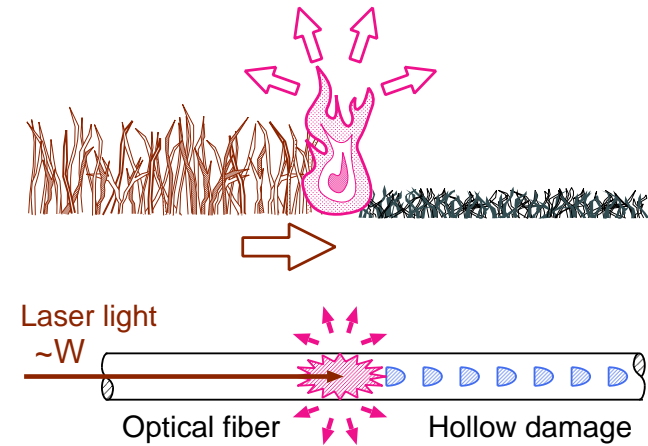
### Control

How we eliminate the breakdown?

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### Direction

### Dissipative soliton



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### Behaviors

Why transparent fibers break down?

### Direction

Why it propagates to the light source?

### Heat-up

Why the transparent waveguide absorbs light?

### Velocity

Why it propagates quite slowly?

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### Behaviors

Why transparent fibers break down?

### Direction

Dissipative soliton consuming the energy of laser light

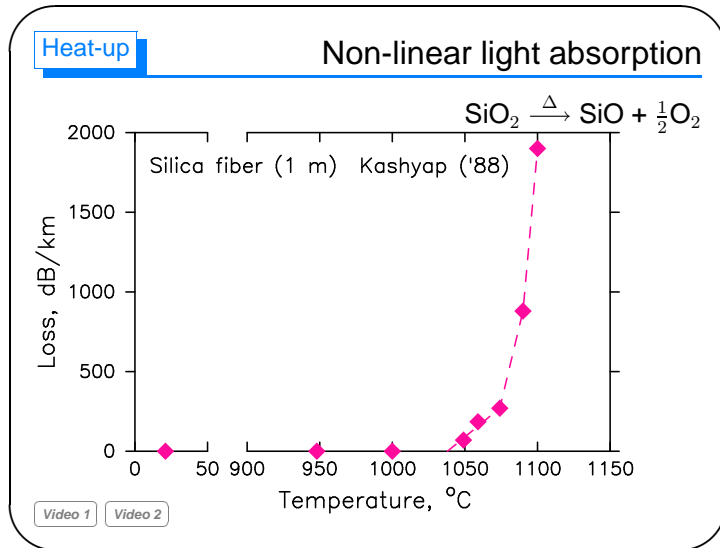
### Heat-up

Why the transparent waveguide absorbs light?

### Velocity

Why it propagates quite slowly?

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**Behaviors**

Why transparent fibers break down?

**Direction**

Dissipative soliton consuming the energy of laser light

**Heat-up**

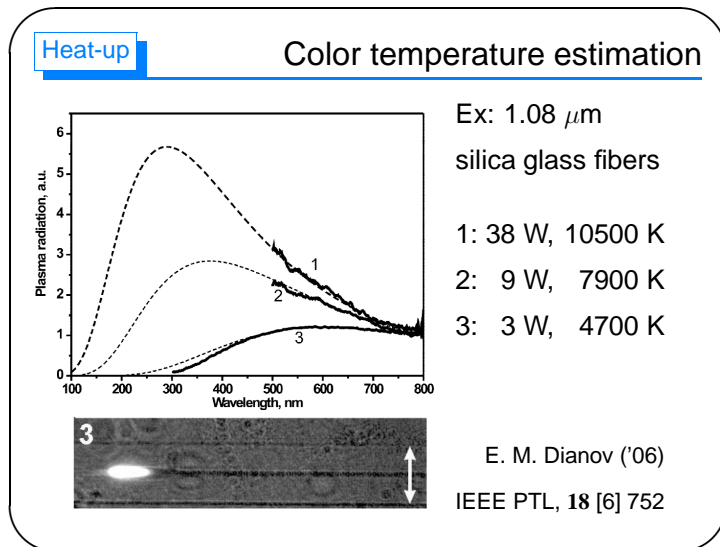
Thermal decomposition products absorb light.

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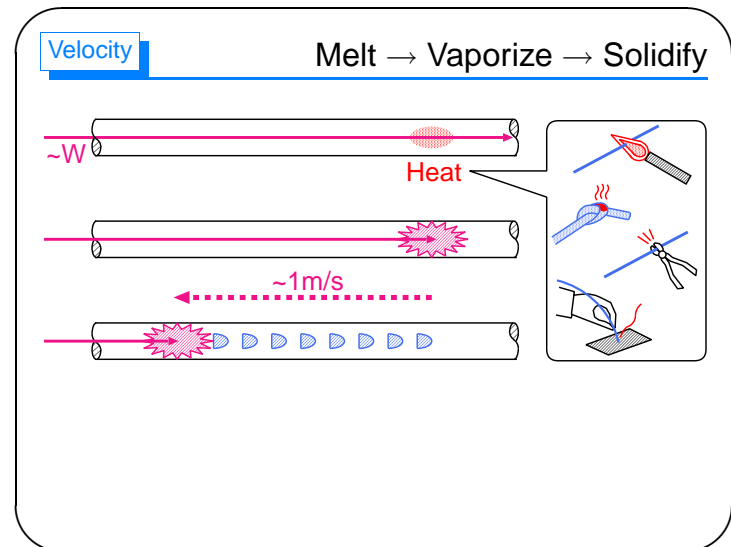
**Velocity**

Why it propagates quite slowly?

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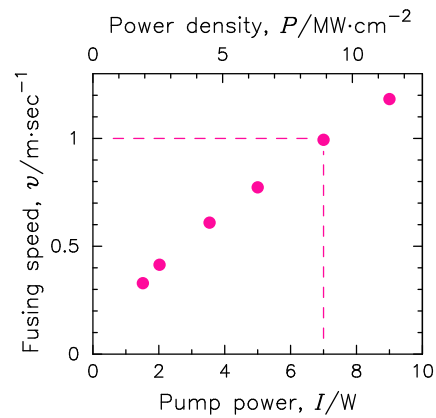
Slide 10



Slide 12

**Velocity****Propagation speed vs. Light power**

SMF-28

**Slide 13****OVERVIEW***Fiber Fuse: its Actions, Behaviors & Control methods***Behaviors**

It propagates like grass fire consuming light energy.

**Actions**

What's happening in the spot?

**Control**

How we eliminate the breakdown?

**Slide 15****Behaviors**

Why transparent fibers break down?

**Direction**

Dissipative soliton consuming the energy of laser light

**Heat-up**

Thermal decomposition products absorb light.

**Velocity**

It propagates via melting, vaporizing &amp; consolidation.

**Slide 14****Actions**

What's happening in the spot?

**Damage**

What is left after the track of fiber fuse?

**In situ image**

What is told by ultra-high speed photos?

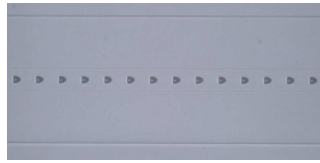
**Periodicity**

Why the voids look like a bullet?

**Slide 16**

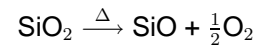
**Damage****What changed after fusing?**

for silica glass fibers:



- O<sub>2</sub> gas in the voids

⇐ Raman microscopy (Kashyap '88)



- Densification

⇐ refractive index increase (Dianov '92)

$$\Delta n_{\text{max}} \sim 0.012$$

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**Actions**

What's happening in the spot?

**Damage**

It leaves periodic & bullet-like voids in core region.

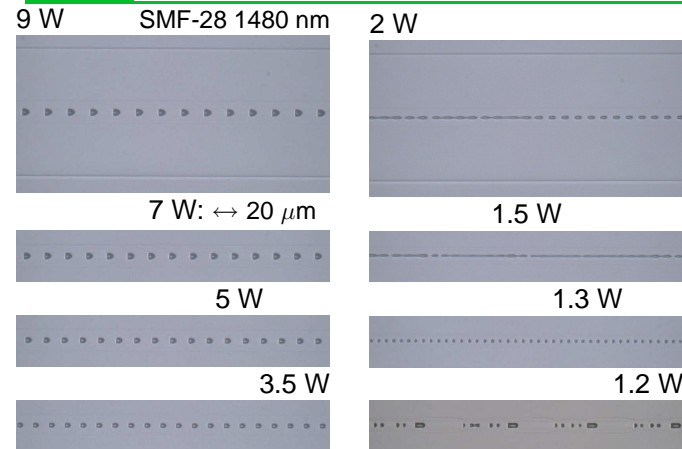
**In situ image**

What is told by ultra-high speed photos?

**Periodicity**

Why the voids look like a bullet?

**Slide 19**

**Damage****Laser power dependence**

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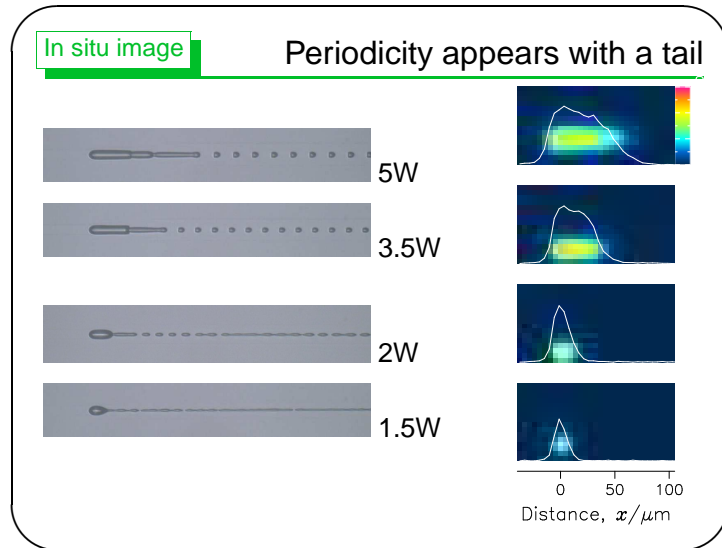
**In situ image****Ultra-high speed videography**

- 4 μs / frame
  - 1 μs-exposure w/ ND filters (×16)
  - 128×16 pixels
  - Wavelength: 380–790nm
- (as in 2004)



Photron Co. Ltd

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**Actions**

What's happening in the spot?

**Damage**

It leaves periodic & bullet-like voids in core region.

**In situ image**

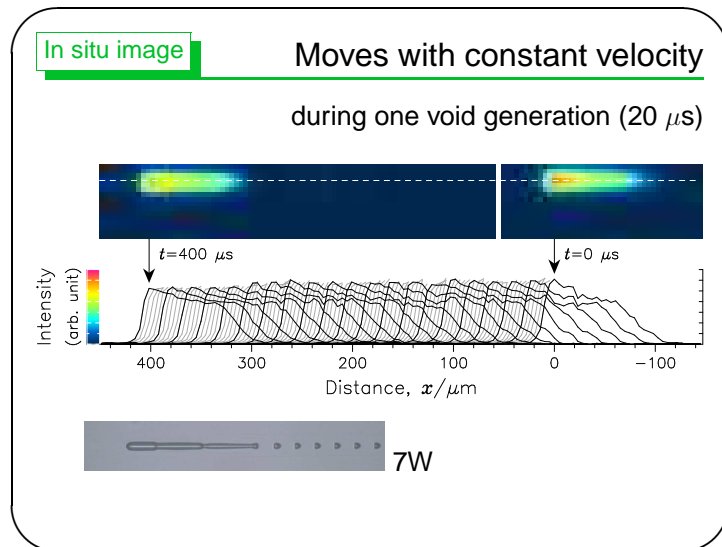
It moves with constant speed during 1 void generation.

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**Periodicity**

Why the voids look like a bullet?

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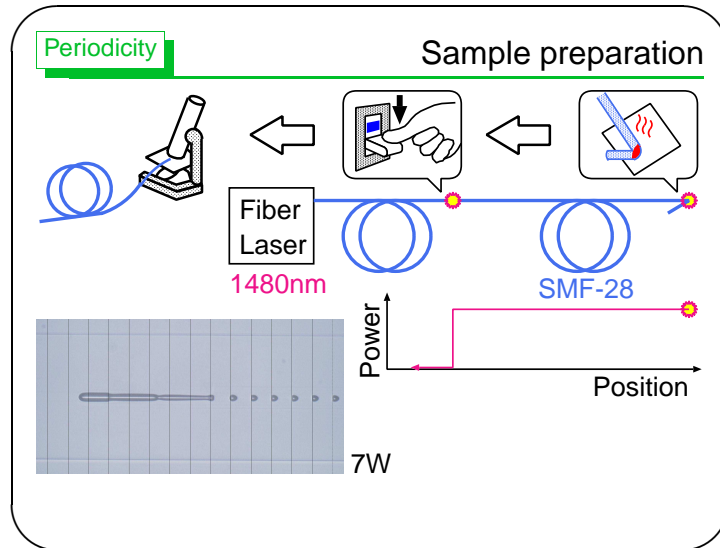


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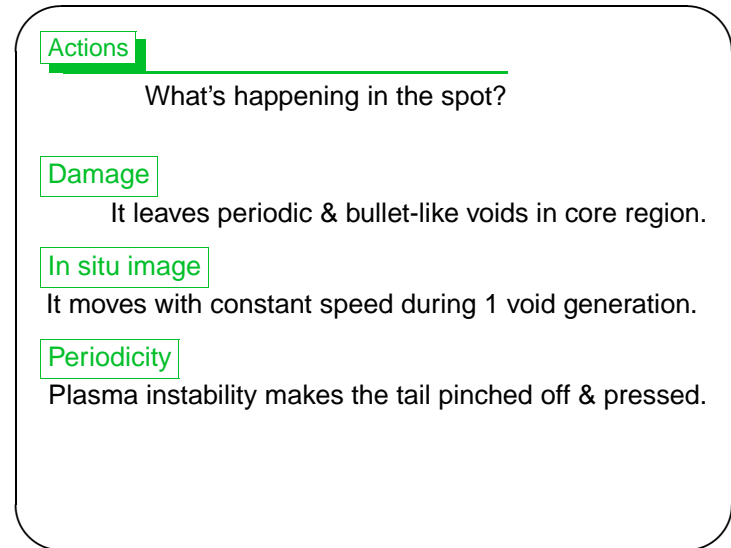
**Periodicity** One day, I had an inspiration.

Slide 24 displays two in situ images of a void in a liquid, showing a series of periodic voids (bullet-like shapes) trailing behind a main void. The images are arranged vertically, showing the same void at different times or positions.

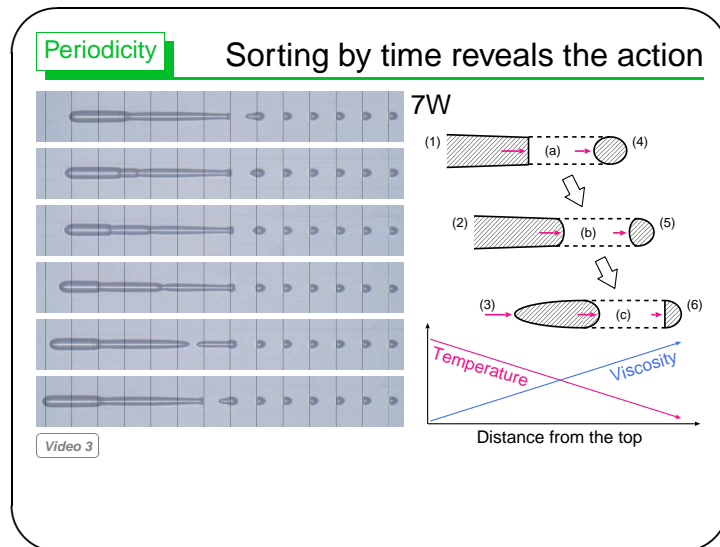
Slide 24



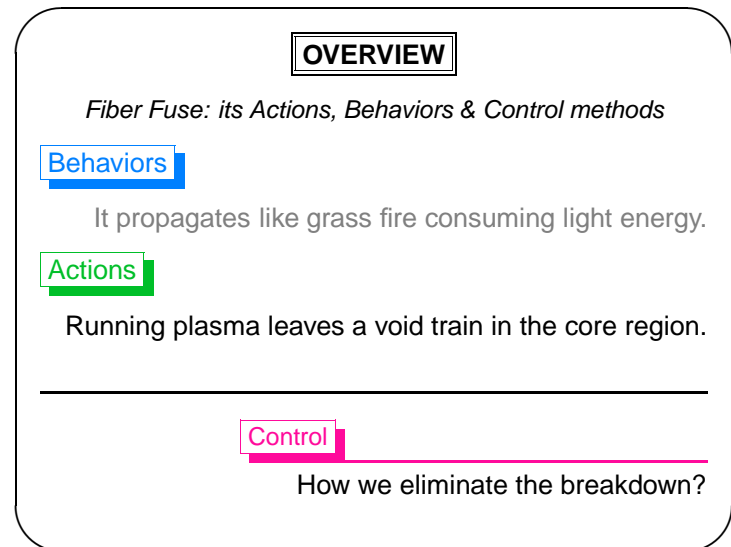
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Slide 27



Slide 26



Slide 28

**Control**

How we eliminate the breakdown?

**Stop the spread**

How we terminate the running plasma?

**First extinguish**

How we detect the emergence of the fuse?

**Nip in the bud**

How we eliminate the excess light?

Slide 29

**Control**

How we eliminate the breakdown?

**Stop the spread**

by inserting a device that destabilizes the propagation

**First extinguish**

How we detect the emergence of the fuse?

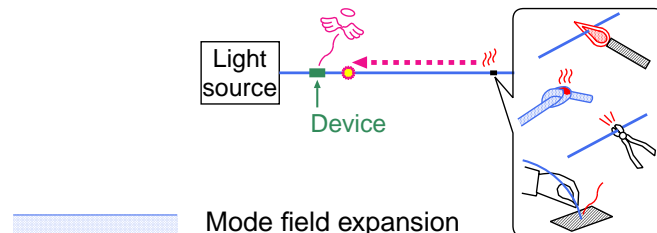
**Nip in the bud**

How we eliminate the excess light?

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**Stop the spread**

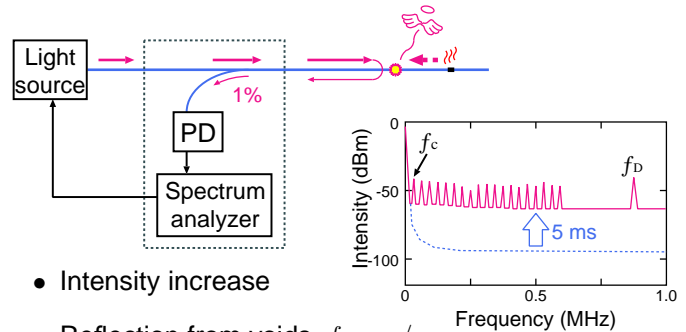
by destabilizing the plasma



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**First extinguish**

Freq. analysis of reflected light



- Intensity increase
- Reflection from voids,  $f_c = \nu/p$
- Doppler shift,  $f_D = 2n\nu/\lambda$

Abedin ('09)  
Opt. Let., 34 [20] 3157

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**Control**

How we eliminate the breakdown?

**Stop the spread**

by inserting a device that destabilizes the propagation

**First extinguish**

after detecting a special signal from the reflected light

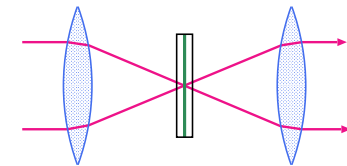
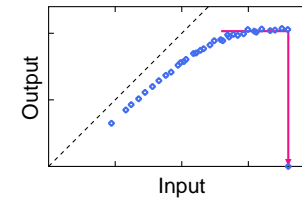
**Nip in the bud**

How we eliminate the excess light?

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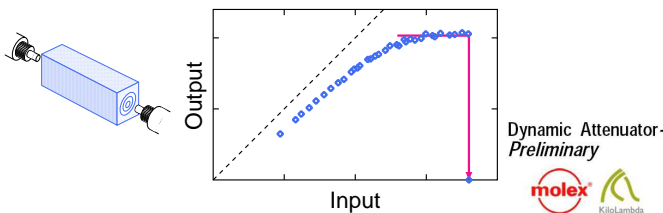
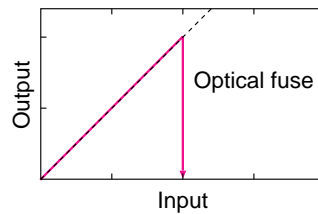
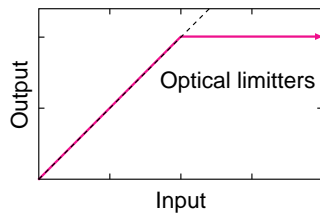
**Nip in the bud****Description in a patent**

- Light absorbing nano-particles in a thin film  
⇒ Heat-induced light scattering



WO 2007/042913

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**Nip in the bud****Devices: Ideals vs. Realized**

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**Control**

How we eliminate the breakdown?

**Stop the spread**

by inserting a device that destabilizes the propagation

**First extinguish**

after detecting a special signal from the reflected light

**Nip in the bud**

Optical limiters are realized using nano technology.

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**Summary** *Fiber Fuse: its Actions, Behaviors & Control methods*

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**Behaviors**

It propagates like grass fire consuming light energy.

**Actions**

Running plasma leaves a void train in the core region.

**Control**

We have symptomatic treatments, but cannot say safe.

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**References**

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1. List of research papers:  
[http://www.geocitis.jp/tokyo\\_1406/node6.html](http://www.geocitis.jp/tokyo_1406/node6.html)
2. Movies: <http://www.youtube.com/tokyo1406>
3. S. Todoroki: "Make the best use of your serendipity by inspiring your audience". (Translated from OYO BUTURI, 78 [7] pp.668-671, 2009).  
<http://www.scribd.com/doc/16980276/>

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