CLIO Development in KAMIOKA and LCGT

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Italy
2006/5/31

LIGO-G060330-00-Z


LCGT Budget Application
(2005-2006)

Budget Application

- **Basic Process**
- Physics Society Support

(Astrophysics, High Energy, Nuclear, Cosmic Ray …)

- Ranking in University of TOKYO
- Ranking in The Ministry of ECSST
- Approval at The Ministry of Finance

- **2005**
- Physics Society Support OK
- Low Ranking in Univ of TOKYO
- Not listed in the plan from The Ministry of ECSST to Finance, then ended.

- **2006**
- Physics Society Support OK
- High Ranking in Univ of TOKYO
- Ranking in The Ministry of ECSST is on progress.

Advertisement

- **Visitors**
  - The minister of the ministry of ECSST (2005)
  - The Secretary of State (IT minister) (2006)
  - USA
  - A party of European Scientific Institutes (2005)
  - Financial staff of the ministry of ECSST (2005, 2006)
  - Pro. Koshiba (2006)
  - Technical Advisory Committee for LCGT (2005)
  - Famous English translator of novel (2005)
- **Public Advertisement**
  - Symposium entitled “The cosmos probed by Gravity”. (ICRR, ERI, NAOJ, ASAHI Newspaper,)
  - Symposium in Amaldi6.
  - Small symposium is planned.


Over Views

Interferometer Design

- Over View -

- **Detector parameters**

Site

Kamioka mine

Laser

Nd:YAG laser (1064nm)

Injection lock + MOPA

Power : 150 W

Main Interferometer

Broad band RSE configuration

Baseline length :	3km (2.7km?)
Beam Radius :	3-5cm
Arm cavity Finesse :	1550
Power Recycling Gain :	11
Signal Band Gain :	15
Stored Power :	771kW
Signal band :	230Hz

Vacuum system

Beam duct diameter :	100cm
Pressure :	10^{-9} Torr

Mirror

Sapphire substrate + mirror coating

Diameter :	25cm
Thickness :	15cm
Mass :	30 kg
Absorption Loss :	20ppm/cm
Temperature :	20 K
$Q = 10^8$	
Loss of coating :	10^{-4}

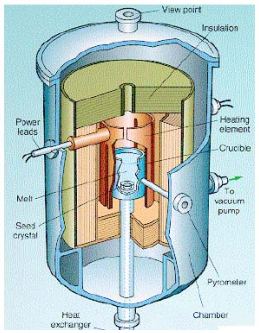
Final Suspension

Suspension + heat link with 4 Sapphire fibers

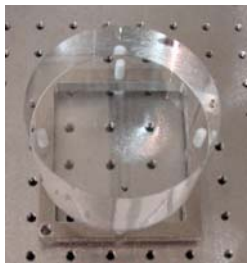
Suspension length :	40cm
Fiber diameter :	1.5mm
Temperature :	16K
Q of final suspension :	10^8


Recent R&Ds

Sapphire Mirror
- Production, Polishing and Coating -



Production



Polishing

Coating

Size:
Substrate (ϕ250 x 150)

Company:
Crystal Systems or
Rubicon Technology

Method:
HEM or ES2-GSA

Issues:
Absorption identification and decrease

Company:
CSIRO or ... ??

Micro Roughness & RMS:
< 1A, 1nm

Curvature & Waviness :
10km order, λ/100

Issues :
These requirements can be satisfied at the same time?

Company:
Japan Aviation Inc

Method:
IBS

Absorption Loss & area :
1 ppm, ϕ250

Issues :
seems to be optimistic.

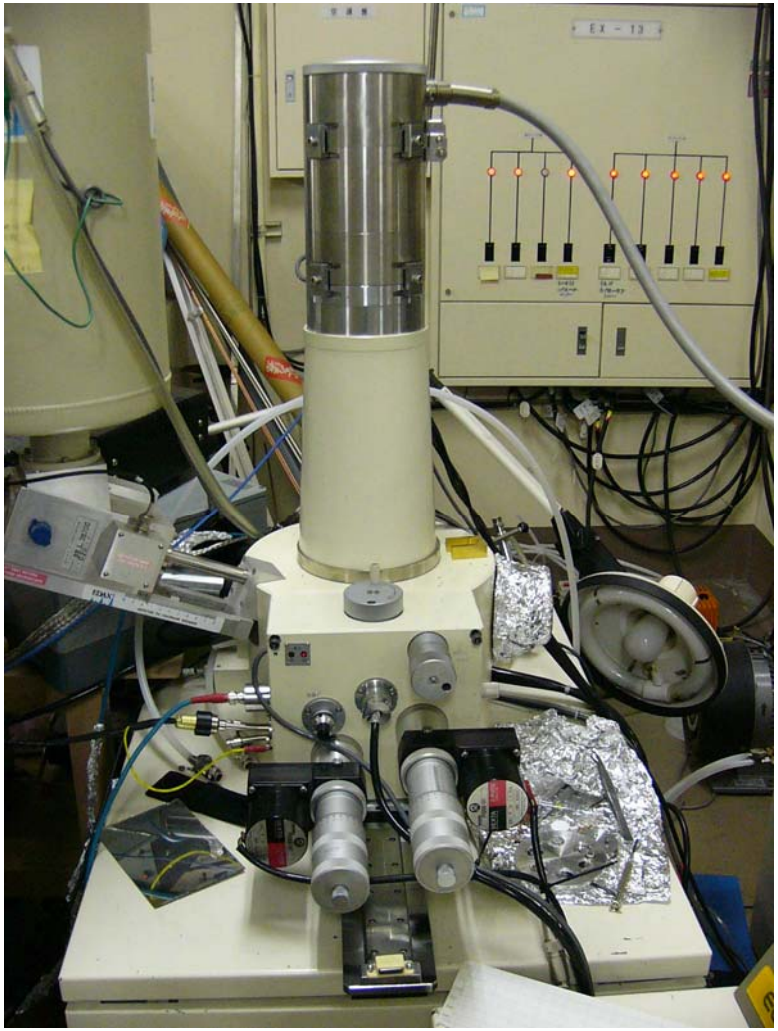
Sapphire Mirror
- Absorption Identification and Its Decrease-

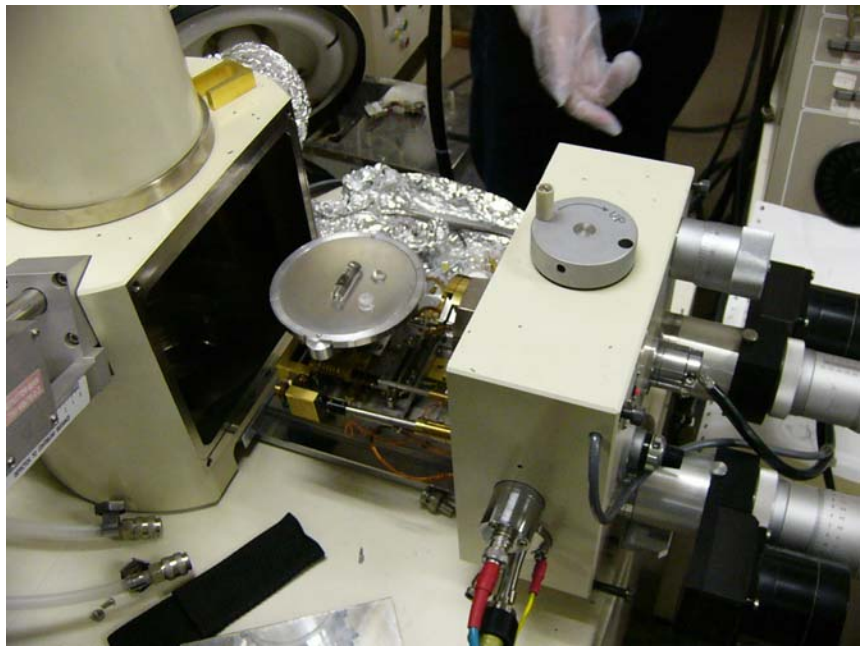
- Laser absorption is important factor for cooling.
- LCGT target
  - Substrate: 20ppm/cm → 250mW
  - Coating: 1ppm → 40mW
- Current status
  - Substrate : 40 - 60ppm/cm (CSI Hemex white grade)
  - 20 - 30ppm/cm (use annealing) (R. K. Route et al., LIGO-G040084-00-Z)
  - Coating: 1ppm (R. K. Route et al., LIGO-G030023-00-Z)

Absorption is close to the target value even now.

Our current cryogenic design is possible to cool the mirror, even if the substrate has 60ppm/cm absorption.

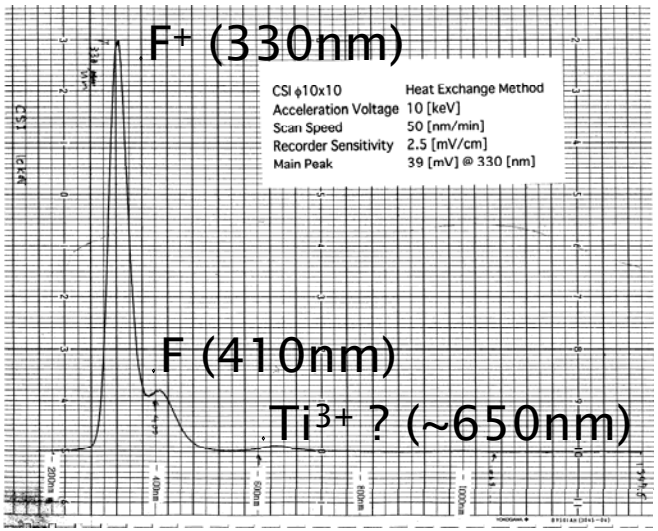
Sapphire Mirror Absorption
- Cathode luminescence Measurement -



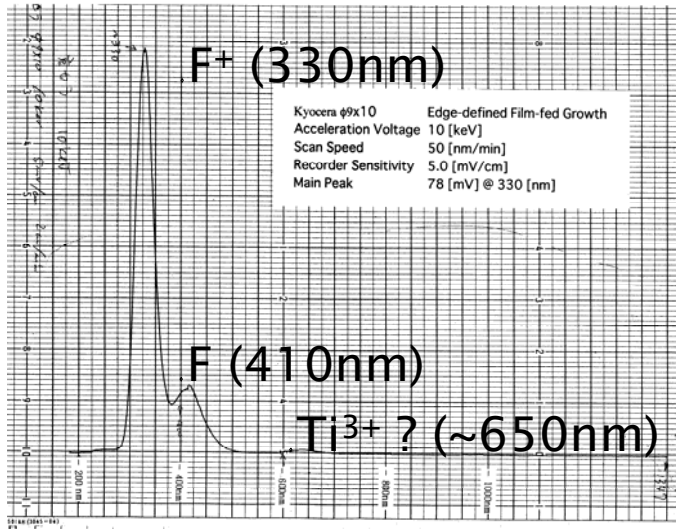


Sapphire Mirror Absorption
- Cathode luminescence Measurement -

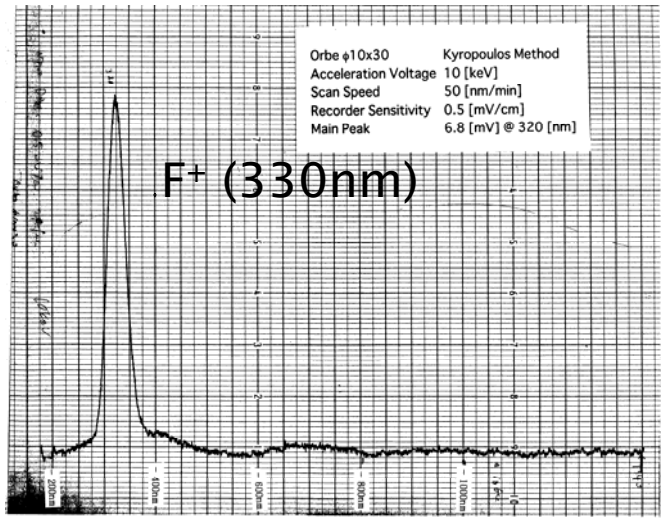
CSI White (HEM)



Kyocera (EFG)



Orbe Pioneer (Kyropulos)



Definition of F center

F : 2 e^- trapped in the lack of O^{2-}

F^+ : 1 e- trapped in the lack of O^{2-}

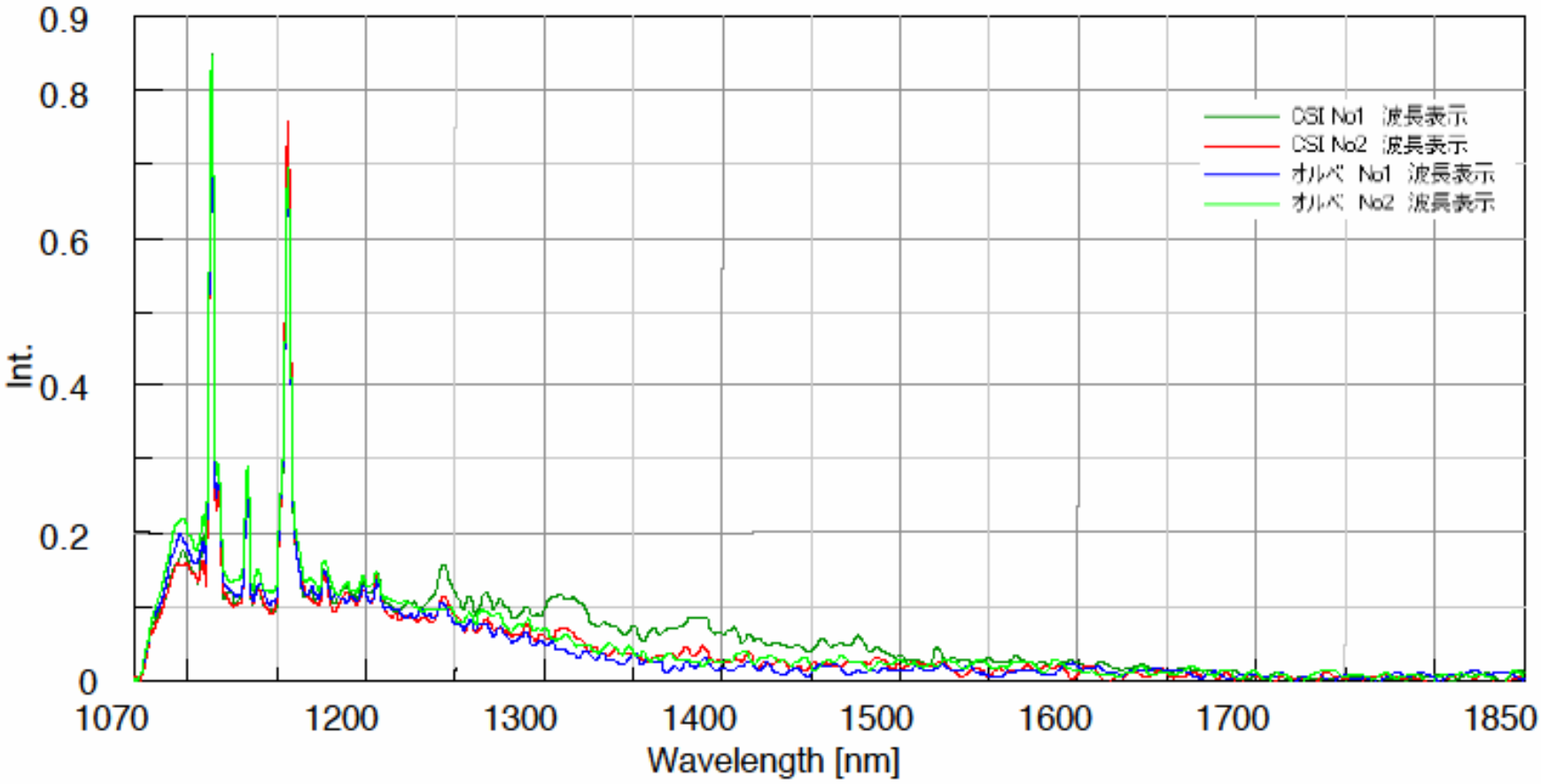
F^{2+} : lack of O^{2-}

F2 : Near by 2 F-center

$F2^+$: 3 e^- trapped in Near by 2 F-center

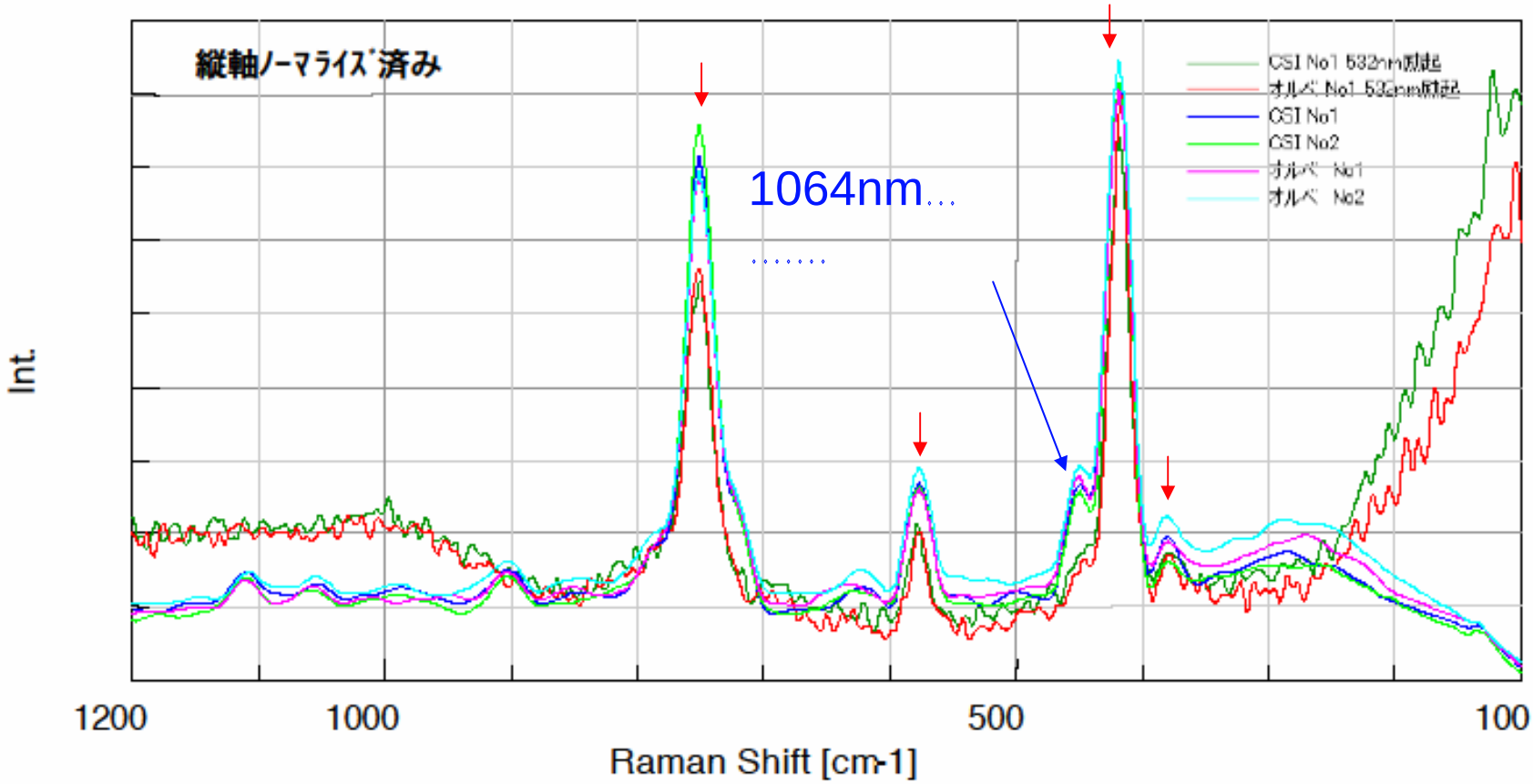
$F2^{2+}$: 2 e- trapped in Near by 2 F-center

Sapphire Mirror Absorption
- Fluorescence using 1064 nm light-



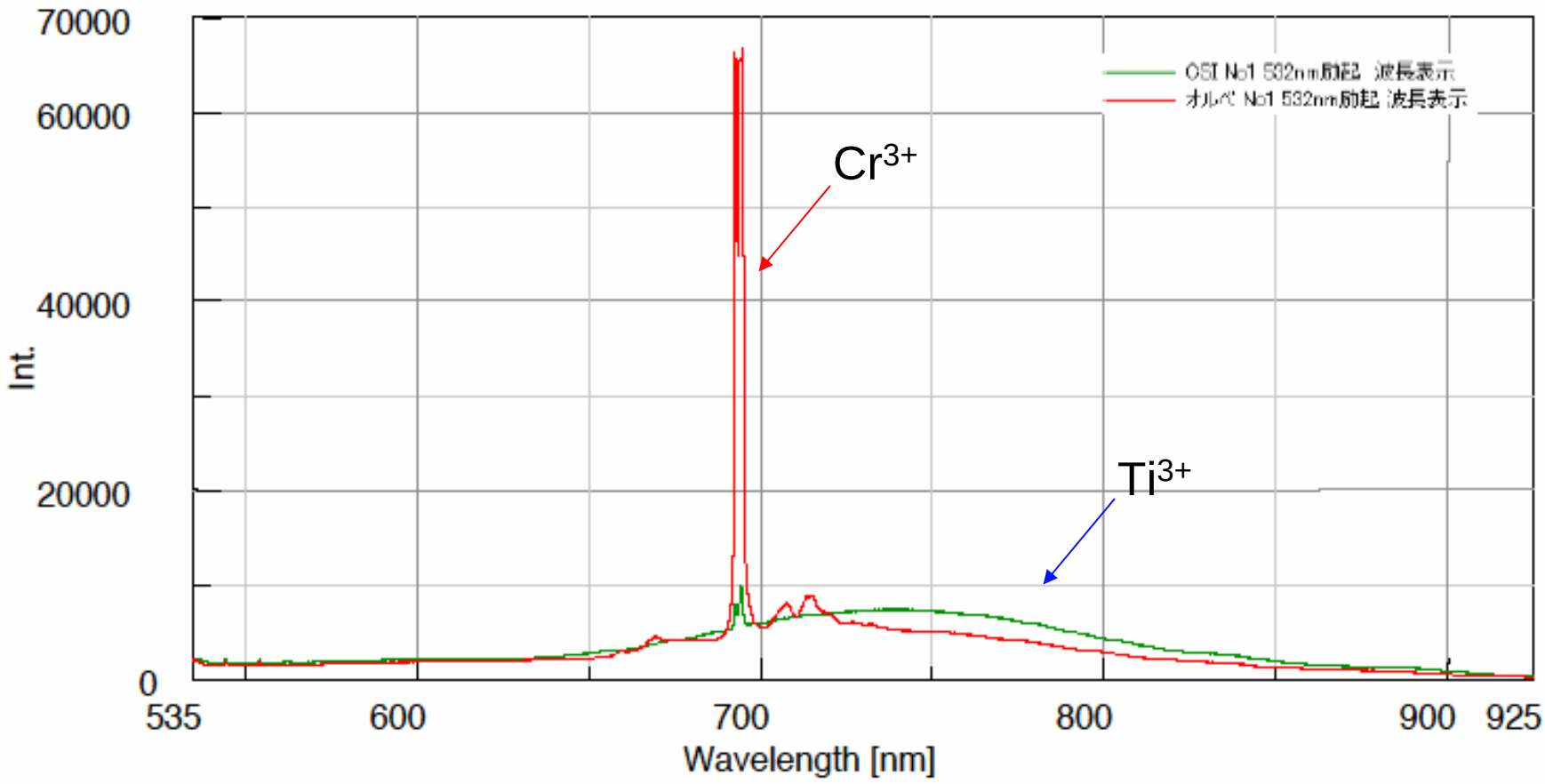
Sapphire Mirror Absorption
- Fluorescence using 1064 nm light (Raman Shift) -

チャート⑮ 酸化アルミニウムのラマンスペクトル(横軸ラマンシフト表示)



ラマンシフト表示にしますと、励起波長を変えても同じラマンシフトの波数位置にサファイヤ(酸化アルミニウム)のラマンスペクトルが検出されているのがわかります。

Sapphire Mirror Absorption
- Fluorescence using 532 nm light-



Amount of Cr^{3+} is quite different between CSI and Orbe Pioneer's, but they shows same level of absorption. Then Cr3+ is not the source of absorption. On the other hand, Ti3+ is relatively same level.

Sapphire Mirror Absorption
- Trial to decrease F center -

Anneal treatment using HIP (Yamanashi Univ.)

If HIP annealing is effective, it contributes to reduction of F center and change of ion number

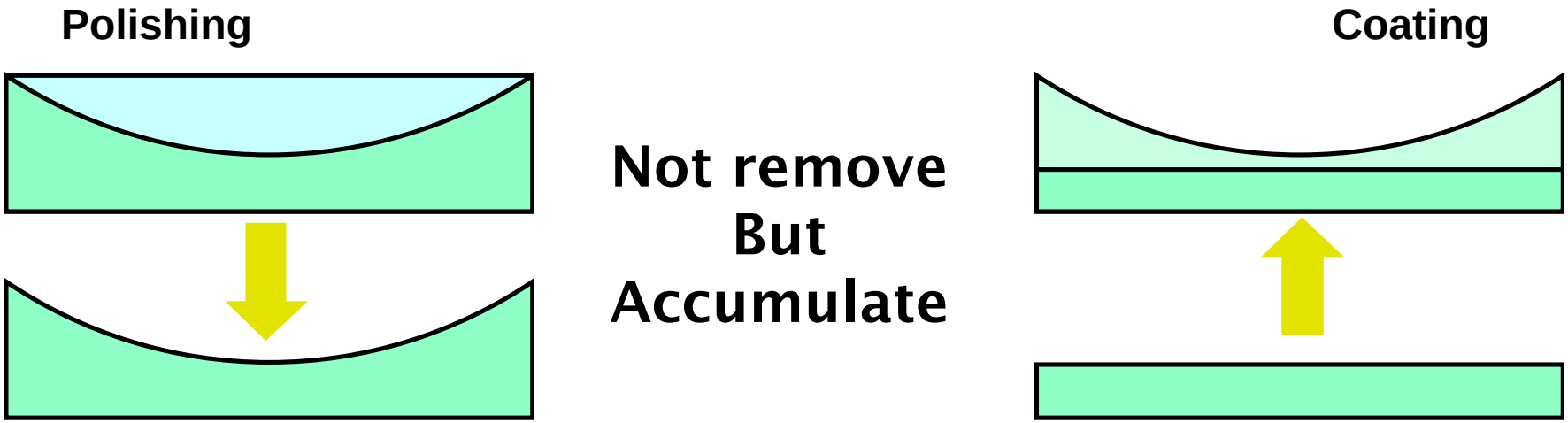
HIP condition
Ar 80%, O_2 20%
Temperature : 1500℃
Pressure :200MPa

Sapphire Mirror Curvature Manufacturing
- Curvature (~10km) production by coating technique -

Q : Low waviness (λ/100) and low micro-roughness (0.1 nm rms) are simultaneously satisfied by the present polishing technique?

A : Not impossible but still difficult ! because the super –polishing treatment, which enables 0.1 nmrms micro-roughness, spoils the waviness.

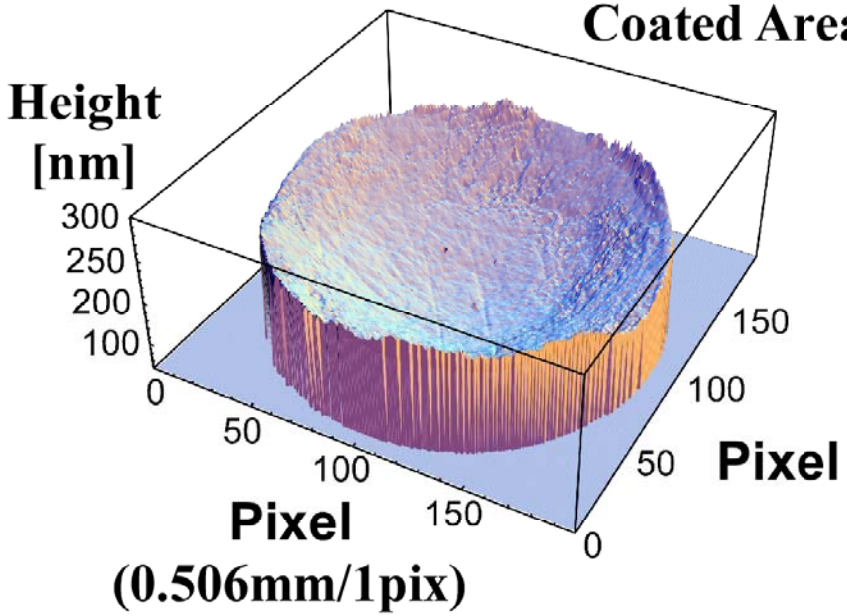
Change the point of view



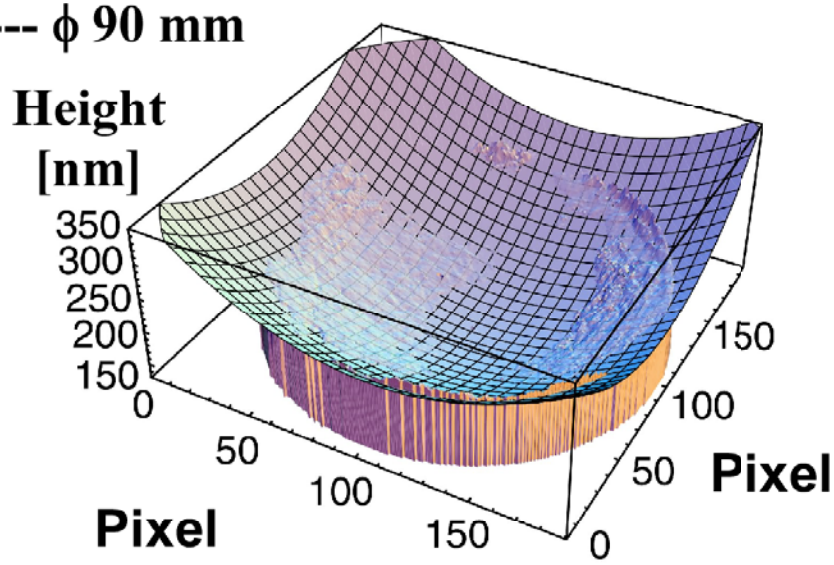
Sapphire Mirror Curvature Manufacturing

- Curvature (~10km) production by coating for SiO2 -

Phase Map

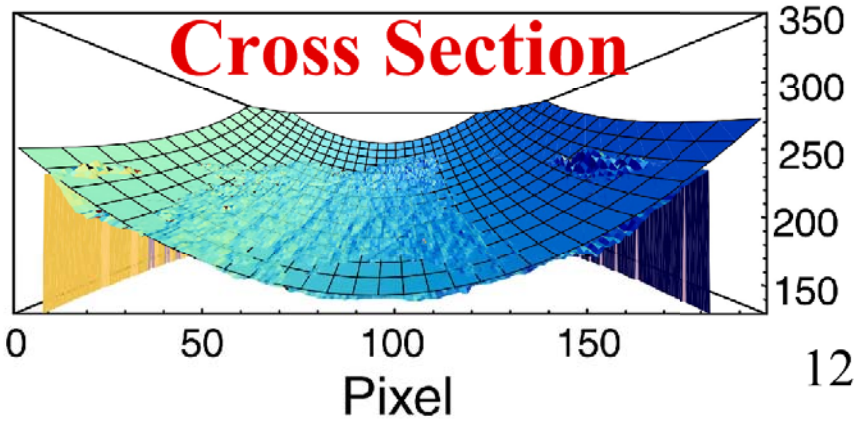


Fitting Curvature



$R = 10255 \pm 120$ m

Measured by ZYGO-GPI-XP
at NAOJ

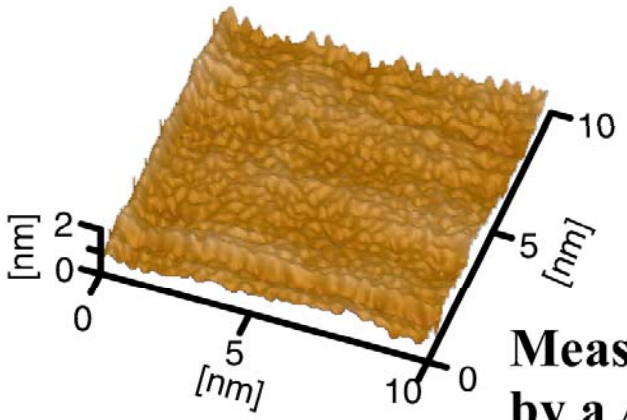


Sapphire Mirror Curvature Manufacturing -
Curvature (~10km) production by coating for SiO2 -

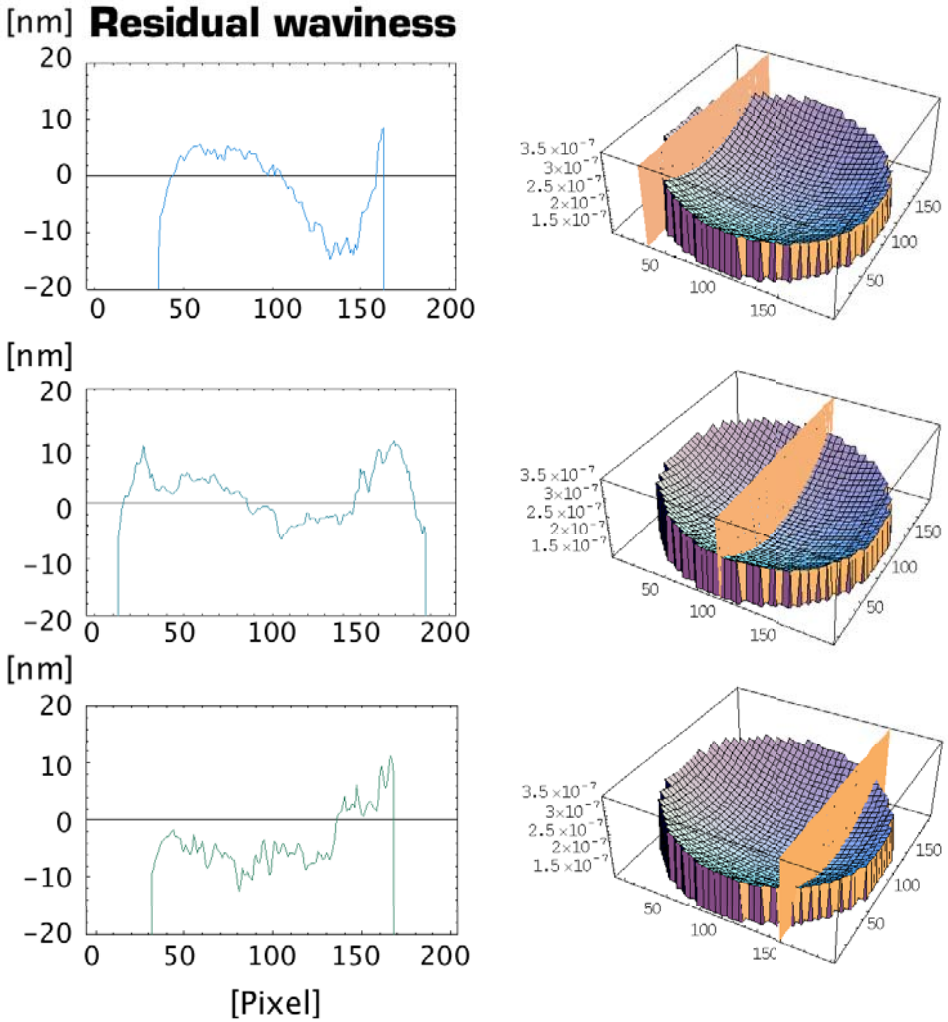
◆ **~20 nm (~ λ/30 < Spec. ~ λ/20)**

Accounting for the result 1 and 3, the waviness was estimated not to be spoiled by the coating film.

Micro Roughness : 0.4 nm

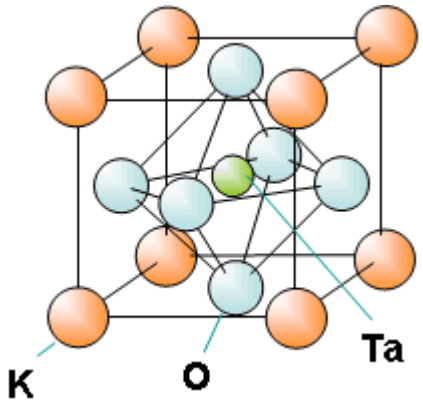


Measured by a AFM

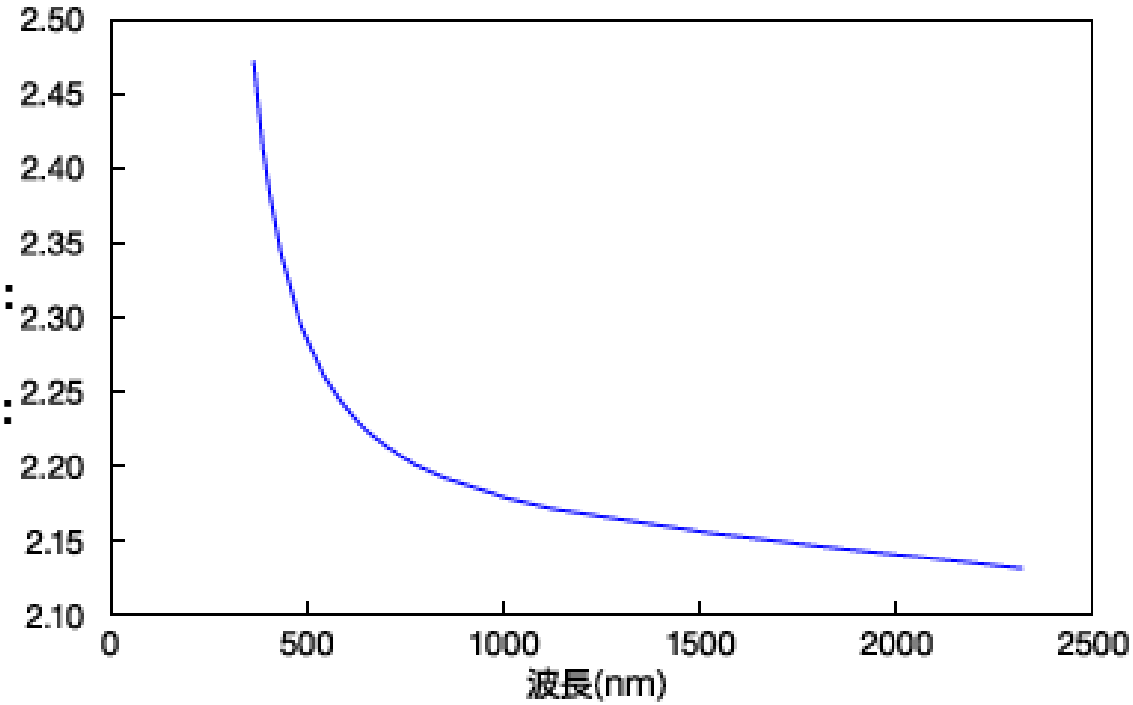


Search for Ta_2O_5 replacement ?
- KT crystal ($KTaO_3$) by NTT advanced technology Inc. -

KT crystal has
- comparable refractive index with Ta_2O_5 (n~2.2),
- transparence from 365nm To 4000nm,
-No birefringence
-Stable



Linear Coefficient of Thermal Expansion
- 30 centigrade to +20 centigrade : 6.3 x 10-6 / .
+20 centigrade to +70 centigrade : 6.7 x 10-6 / .
Abbe's Number
.d = 17.3 (@ 28 .)



Sapphire Fiber Bonding and Bending
- How to suspend ? -

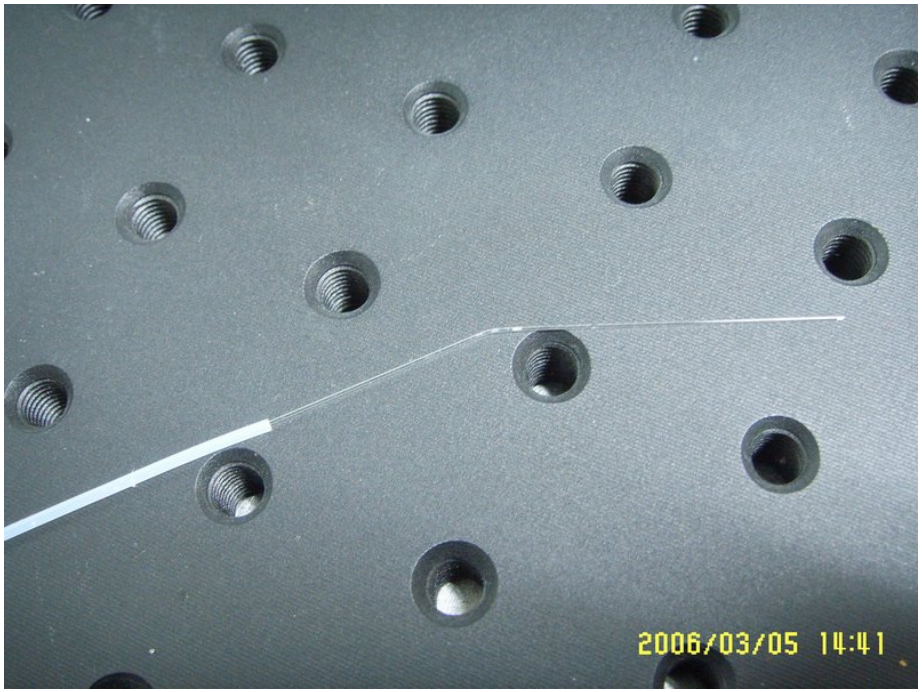
There are two approaches
(1) Bonding between the mirror and the fiber

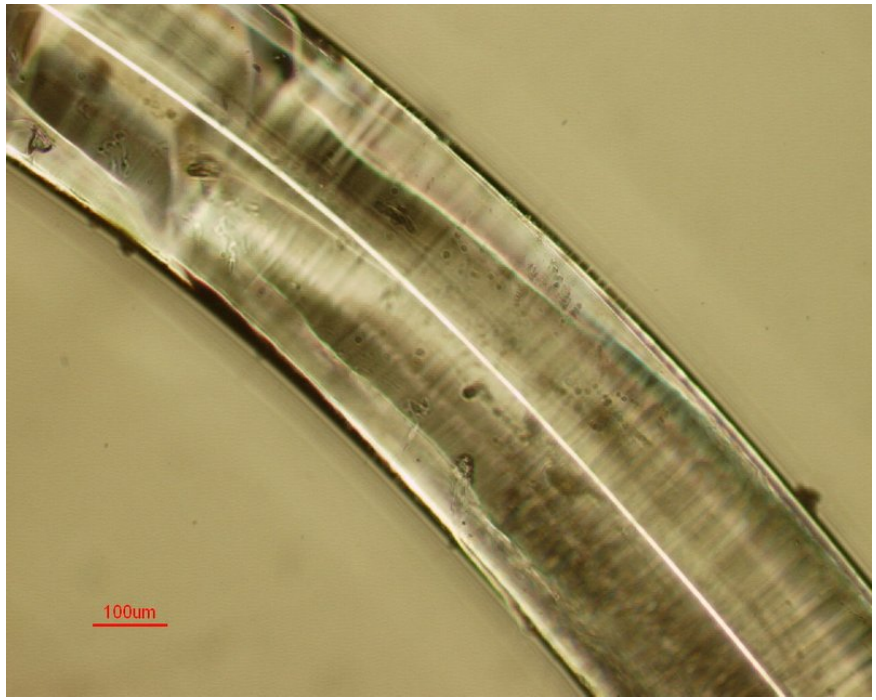
(i) Direct bonding.
(ii) Bending using heat treatment.

(2) Shape machining into U – shape

Elastic bending using CO2 Laser Heating
- ϕ 425um fiber -

CW 50W CO_2 LASER , spot~2 mm





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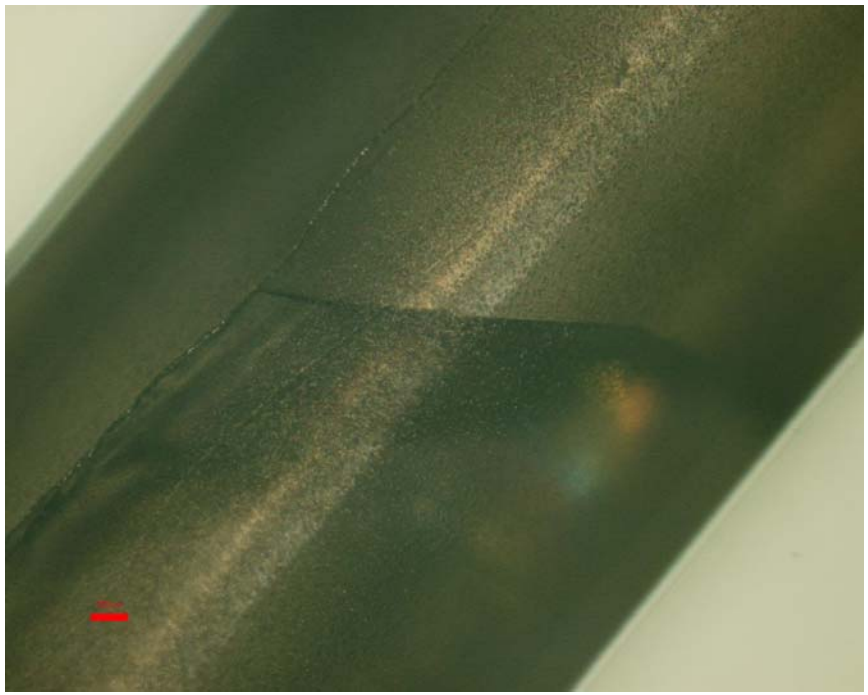
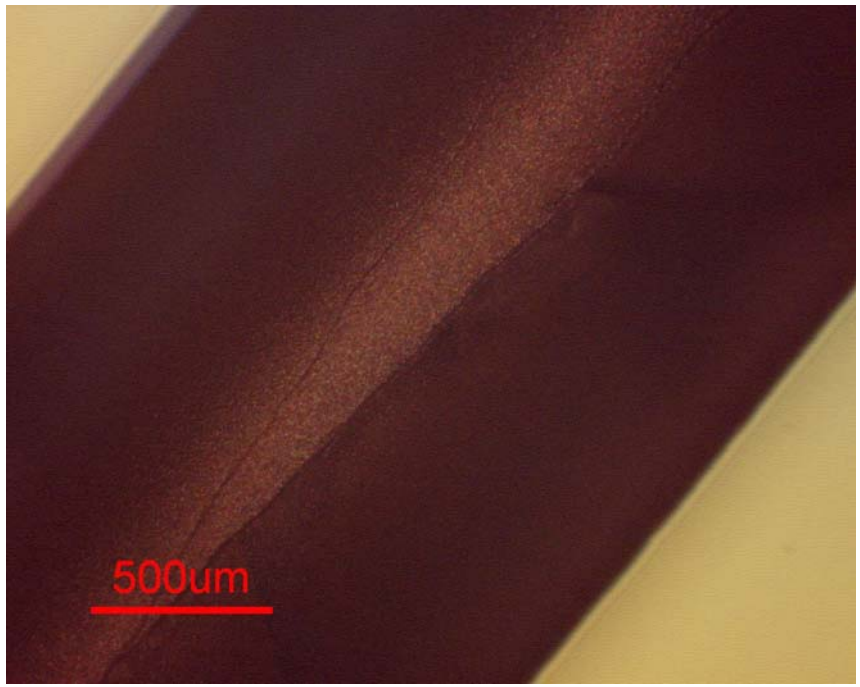
They successfully bent the sapphire fiber without cracks.

More practical shaping, strength Q and thermal conductivity measurement will be planed.

Elastic bending using CO2 Laser Heating
- ϕ 1.8mm fiber -

CW 80W CO_2 LASER Spot ~ ϕ2mm





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Cracks took place because of small spotting and steep temperature gradient. Now they are preparing high power CO2 laser and bending mechanics.

Summary of LCGT

-In 2006, LCGT will be proposed to the ministry of ECSST from the University of TOKYO as a high ranked project.

-LCGT budget is strictly requested to be cut.
From $160M(2005) to $140M(2006).

-Several R&Ds about sapphire substrate, polishing and bonding (bending) techniques have been kept going small step by step.