

펨토초 레이저 응용 극미세 가공 기술

Ultra-precise material processing using a femtosecond laser



한국기계연구원

KOREA INSTITUTE OF MACHINERY & MATERIALS

펨토공정연구실

www.femto-kimm.kr

shcho@kimm.re.kr



한국기계연구원

KOREA INSTITUTE OF MACHINERY & MATERIALS

광응용기계연구실장, UST 나노메카트로닉스 전임교수

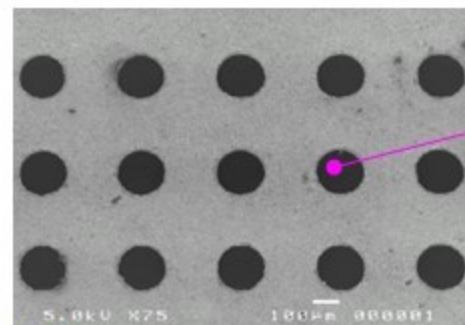
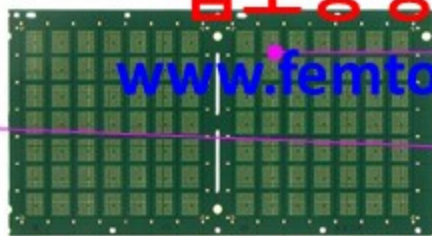
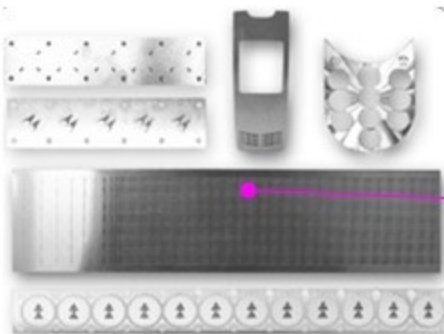
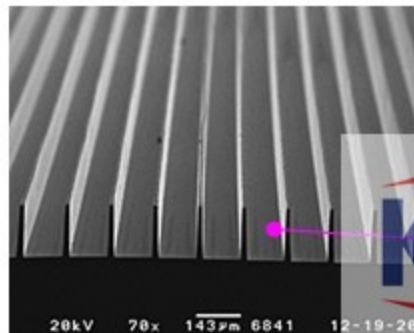
http://www.femto-kimm.kr

목 차

- ❖ 연구배경 - 수요 현황, 시장 규모
- ❖ 극초단펄스 레이저란?
- ❖ 펄스 레이저 가공 장점
- ❖ 펄스 레이저 기반 가공 시스템 제품화 상용화 예
- ❖ **Research Topics with femtosecond laser in KIMM**
 - Internal Material Processing 펄스 가공 연구실
 - Surface Material Processing
 - 펄스 레이저 응용 생체 세포 조작 및 진단 기술 개발
 - 투명유리 내부 색상 구현 기술 연구
 - 펄스 레이저 응용 반도체 건식 세정 연구
 - 현재 진행 중인 국책 과제 소개
- ❖ 펄스 레이저 미세 가공 활용 지원 지원 사례
- ❖ 결론
- ❖ 안내 (Announcement)

연구개발 필요성 (1) - 미세 형상 가공 수요 급증

미세가공 형상 공정 기술 수요 기업 1



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보안필름

고휘도 광학필름

EMI 필터

PCB/FPCB 기판

휴대폰부품, 케이스

X-ray 형광판

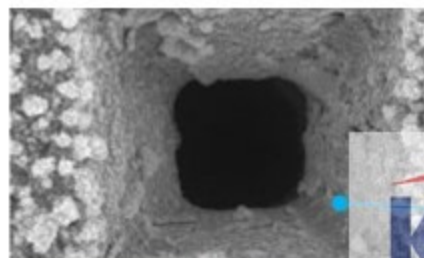
바이오칩 미세홀

기술 수요 기업

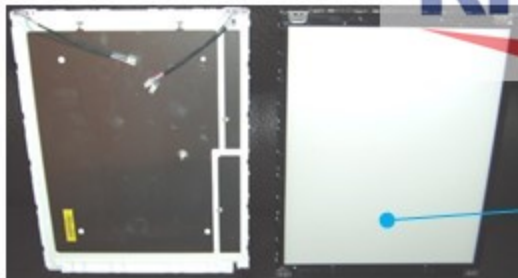
- (주)삼성SDI
- 중앙연구소
- (주)엘엠에스
- (주)에닉스
- (주)맥스필름
- (주)마이크로홀
- (주)제이피이
- (주)피엔티
- (주)나노솔루션
- (주)케이메트로
- (주)오토파워
- 한독기계(주)
- 소닉스코리아
- (주)엘티에스
- (주)덕 유
- 호 나
- 나노전광 주식회사
- 휴메드 주식회사
- 조폐공사
- 코닉시스템
- 포스트 마이크로

연구개발 필요성 (II) - 미세 형상 가공 수요 급증

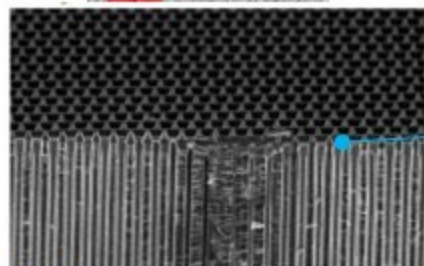
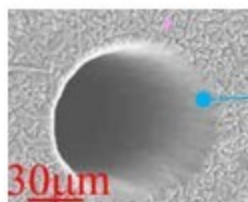
미세가공 형상 공정 기술 수요 기업 II



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● 각종 valve

● 금형부품

● 연료전지

기술 수요 기업

- 이피코리아
- 하나 마이크로
- 삼성전기
- 샤프정밀
- 엘지 마이크로
- 동산금형
- (주)세진
- (주)원플러스투
- KDS intech
- 진영정밀금속
- 뮤텍코리아
- 연백정공
- 도양엔지니어링(주)
- (주)유비프리시전
- (주)네온테크
- 블루플래닛
- 삼성전자
- 생산기술연구소
- 재영솔루텍
- 대산정밀
- 삼도프레스(주)

시장특성 - 미세 레이저 가공기 시장

시장 특성

- 신 성장 고부가가치 산업의 발달에 의해 **초미세 초정밀 가공시스템 수요 증가**
- 초정밀/초미세 가공장비는 기술 첨단화로 **일본/독일이 세계 시장 주도**
- 핵심부품 대일/대미무역 역조품으로 **국산화 기술 개발 시급**

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(OPTTECH, 독일, 2008)

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레이저미세가공시장



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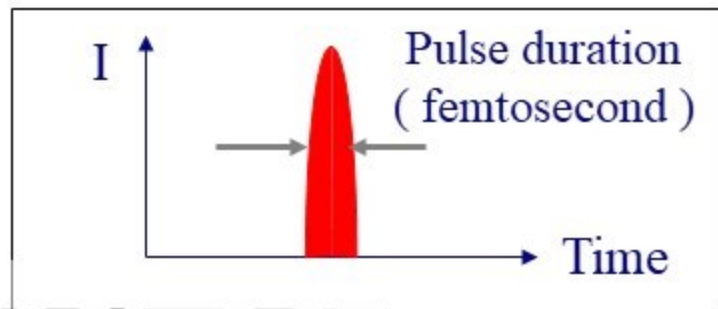
구분	2008년	2010년	2012년	2014년	2016년	
세계 시장	금액 (천억원)	28	37	49	65	85
	점유율 (%)	4	5	7	10	12
국내 시장	금액 (천억원)	2	4	5	7	8
	점유율 (%)	15	15	16	20	22

- 레이저 미세 가공기: 2008년 세계시장 2.8조원, 연성장을 17.2%로 전망
- 2016년 기준 국내시장: 8,000억원, 세계시장: 8.5조원
- 2차 생산제품시장 [미세금형, 디스플레이, 의료부품, 바이오기기등..] 비중/성장을 높음

펨토초 레이저 (광펄스)란?

Laser output pattern

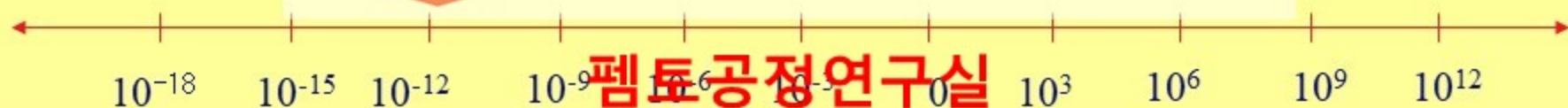
1. Continues Wave Laser (CW laser)
2. **Pulse Laser**



Prefixes for Units



Atto femto pico nano micro milli kilo mega giga tera



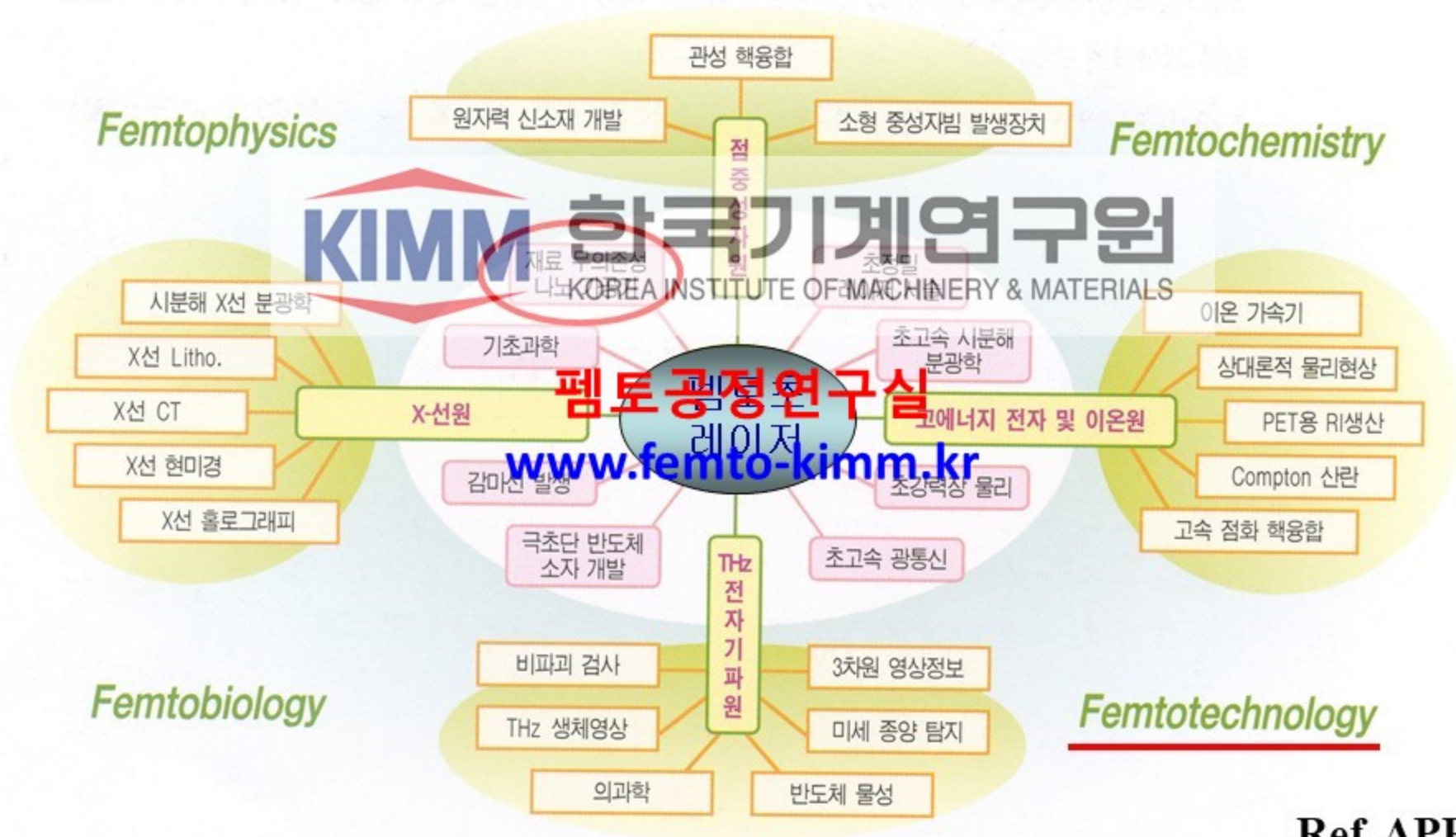
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Ultrafast laser
(Pulse duration: ~100fs, 800nm)

⇒ **Femtosecond (10^{-15}) laser**



Application of Femtosecond Lasers



Ref. APRI

New material processing tool using an ultrafast laser

Interaction
Mechanism

- Shorter laser-matter interaction time than energy diffusion time
- No hydrodynamics of matter under laser irradiation time
- Many nonlinear processes (multi-photon absorption, self-focusing...)

Concept



Femtosecond ablation

Nanosecond ablation

극초단펄스 레이저를 이용한 가공



높은 침투 출력	비선형 흡수	가공 threshold를 낮춤 낮은 etch rate는 미세가공에 용이함 투명, 취성 재질 가공에 용이함
짧은 펄스 폭	$t_p < t_e < t_l$	HAZ (Heat Affected Zone) – free machining

다광자 흡수 프로세스의 기본 원리

basic physical processes (in dielectrics)



Long pulse (**nanosecond**) laser machining

Pulse duration: 5 ns



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Short pulse (**femtosecond**) laser machining



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Nanosecond laser vs Femtosecond laser in Machining

Long pulse (**ns**) laser

Short pulse (**fs**) laser



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펄토초 레이저의 상용화 예 : 안과 라식수술 (I)



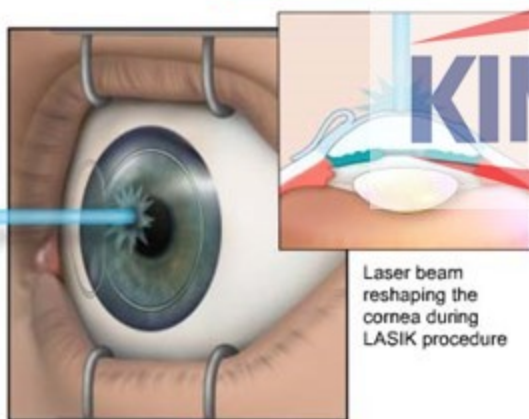
U.S. Food and Drug Administration



CENTER FOR DEVICES AND RADIOLOGICAL HEALTH

국 외

FDA approves femtosecond laser for creating LASIK



Laser beam reshaping the cornea during LASIK procedure

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http://www.lasikindia.com/html/lasik_femtosecond_laser.html

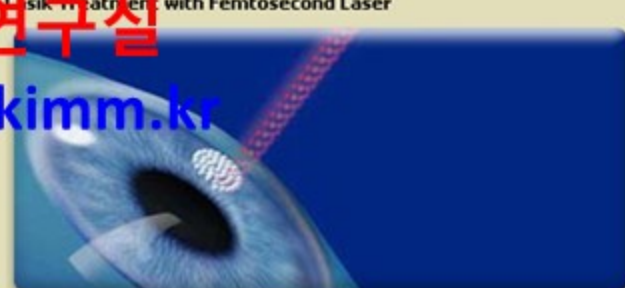
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Sub - links

Lasik with femtosecond Laser

1. About Lasik
2. Custom Lasik
3. Lasik treatment with Femtosecond Laser

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Description:

This new state of the art laser cuts the LASIK corneal flap without the need for a mechanical device that uses a blade (microkeratome).

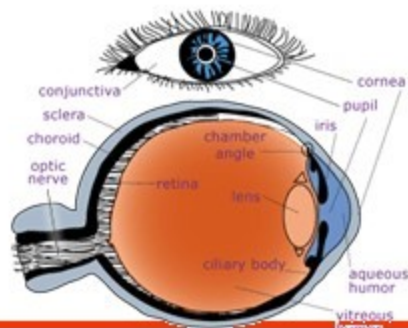
Distinction

This "Bladeless" procedure produces a flap that is much more precise in depth while being cleaner. This is perhaps the biggest leap in vision correction surgery since the introduction of the original Lasik in 1998.

Suitability

Since the femtosecond laser is a high technology replacement for the mechanical microkeratome, Femtosecond laser LASIK is suitable for

Quicklinks



펄펄초 레이저의 상용화 예 : 안과 라식수술 (II)



시대를 뛰어넘은 Hi-Technology 레이저

DA VINCI

FEMTOSECOND SURGICAL LASER

다빈치 레이저

KIMM

한국기계연구원

기존의 펄펄초 레이저에 비해 1/2 이하의 레이저 출력

문제에 대하여 해결방안을 제시한 신개념

펄펄초 레이저

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국내

다빈치 레이저란?

- 60Khz, 200Khz시대를 뛰어넘는 가장 빠른 1000Khz이상의 Mhz 레이저!!
- 2마이크론보다 작은 레이저 빔 사이즈(기존의 약 1/2 조사면적)
- 미국, 유럽이 인정한 차원이 다른 최첨단 레이저!!

간략소개

DA VINCI Laser는 라식수술 시 각막을 레이저로 절편하는 Femtosecond Laser입니다. 이미 유럽, 미국과 일본 등의 우수한 라식센터에서 도입되어 활발히 시술 중이며 유럽CE, 미국 FDA와 한국 KFDA 등의 승인을 통해서 안정성까지 입증된 최첨단 레이저입니다.

DA VINCI Laser는 최초의 Compact Mobile femtosecond laser시스템을 채용해 더 안전하고 정확하며 편안한 방식으로 수술이 이루어집니다.

인용:

<http://blog.daum.net/lasik112>

첨단 라식수술의 진화

펄펄초 레이저 시스템
1000kHz(FEMTO
LASER SYSTEM
1000kHz)를 라식수술



강남박은세상안과
BS EYE CENTER

Stealth Dicing Technical



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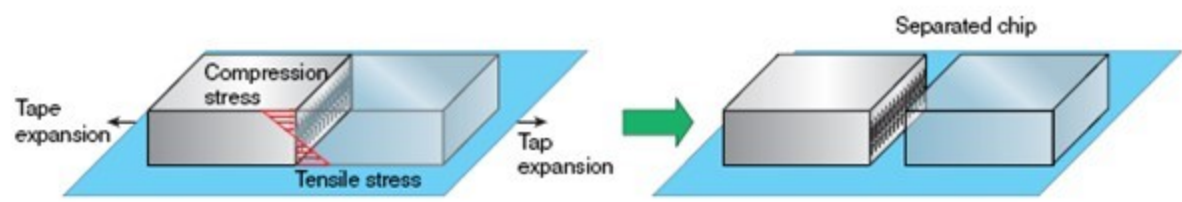


Figure 4: Step 2 - Separation process

TLAS0024EA

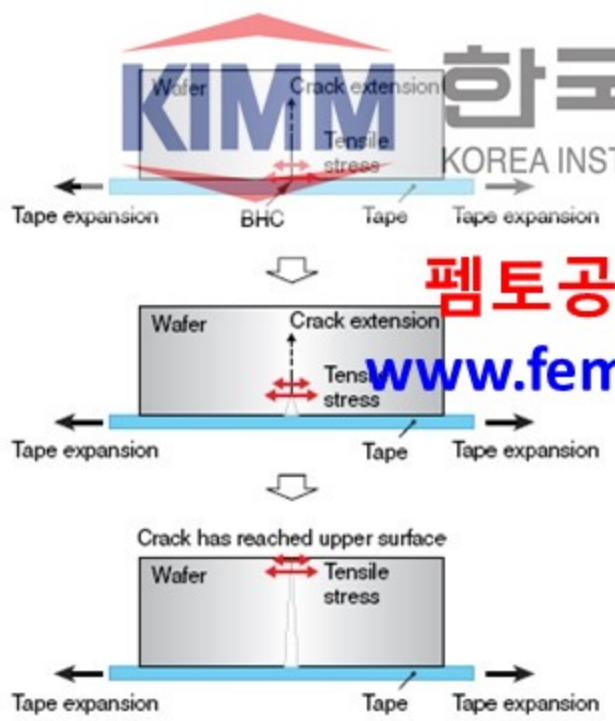


Figure 5: Crack extension principle

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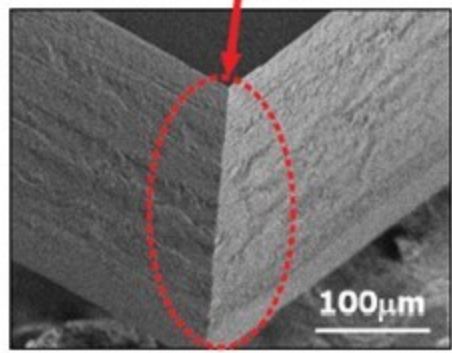
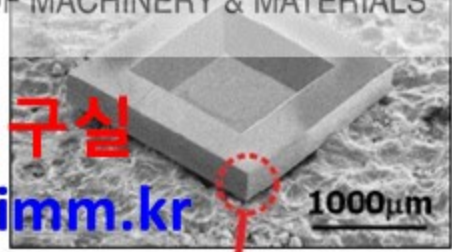


Photo 2: Photograph of chip cut by stealth dicing

results from focusing the laser beam on an internal point of the wafer.⁷⁾

A unique feature of stealth dicing is that the laser beam first irradiates an internal point in the material and starts cutting from that

greatly according to the laser beam depth.⁷⁾ Directing the laser beam on the interior of the wafer during laser process was found more effective in keeping a small heat distribution area than the conventional surface-focused laser process.



Photo 3: Comparing stealth dicing (internally focused laser dicing) with laser surface process

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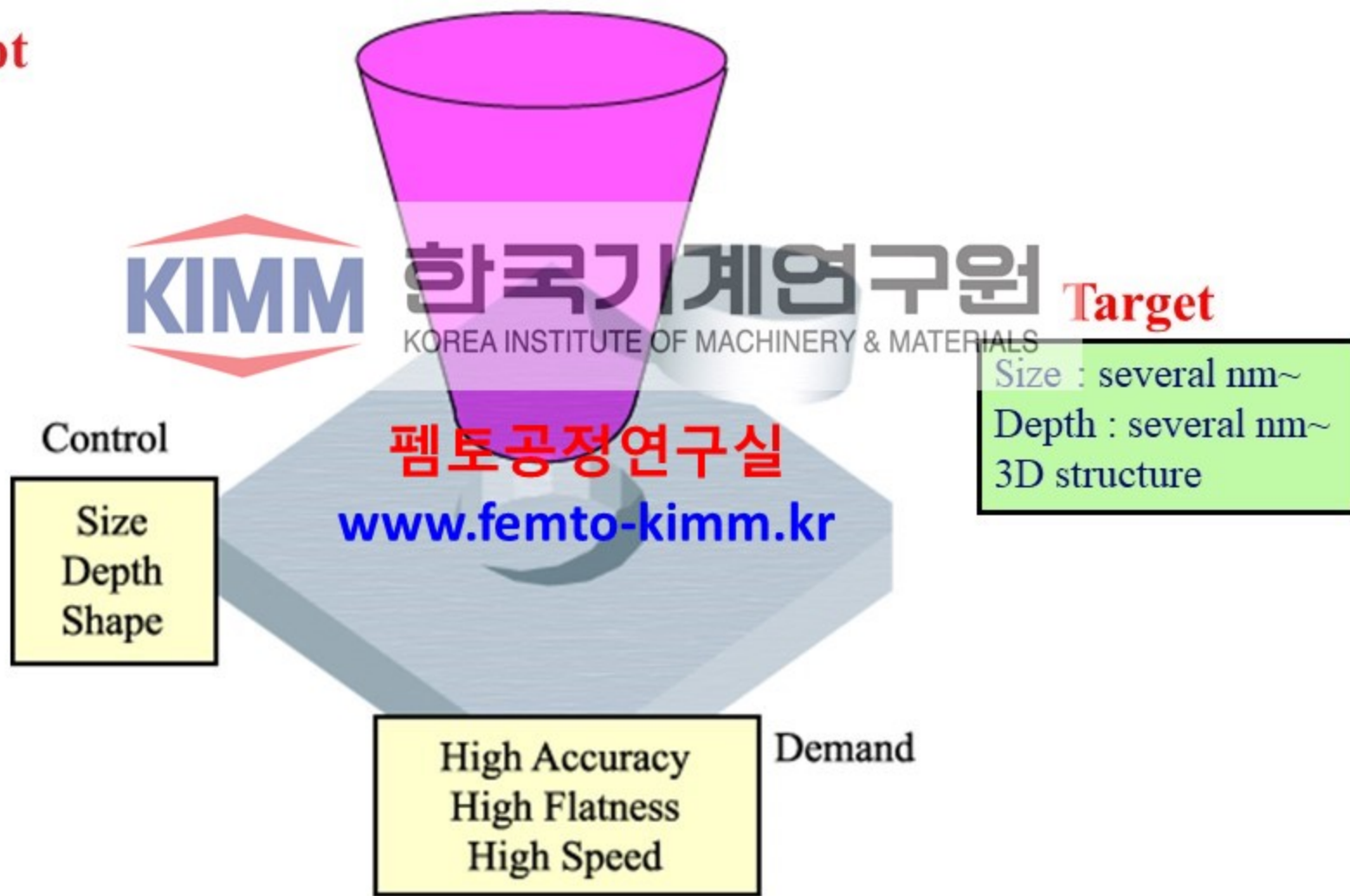
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KIMM 펨토초 레이저 연구 개요

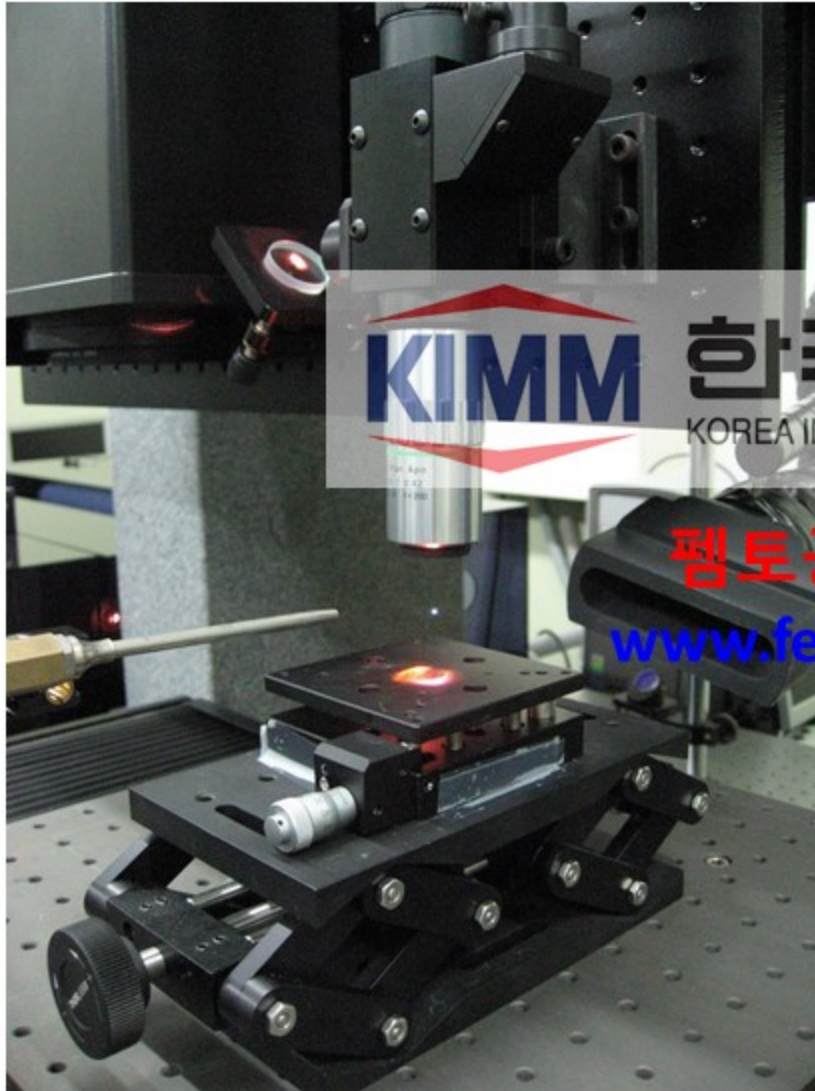


Femtosecond laser direct processing

Concept



Low density plasma formation using fs laser



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fs 레이저 시스템 (I)

➤ *Photograph of Femtosec. Machining System*



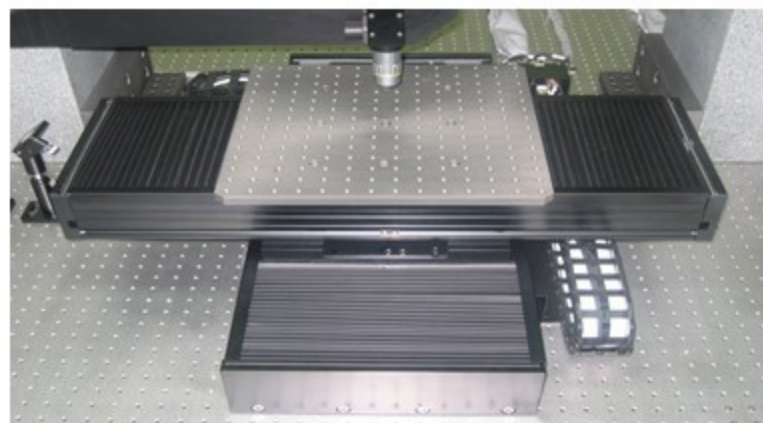
레이저 시스템 (II)

➤ Femto-second laser & XY stage

[Specifications of Laser]



Laser source	Ti:Sapphire
Wavelength	$\lambda = 790 \text{ nm}$
Pulse energy	3.5 mJ/1 kHz
Pulse duration	120 fs
Beam Diameter	8 mm
Beam Quality(M^2)	≤ 1.8
Beam Mode	TEM ₀₀ Gaussian



[XY axis stage]

Working area	300 × 300 mm ²
Resolution	5 nm/count
Position accuracy	2 μm
Repeatability	$\pm 1 \mu\text{m}$

레이저 시스템 (Ⅲ)

➤ Process software

Measurement tool

Attenuator

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- 각 구간의 공정변수 입력가능
- DXF, PLT, G-code 파일 converting

Internal processing in bulk silica using a tightly focused femtosecond laser



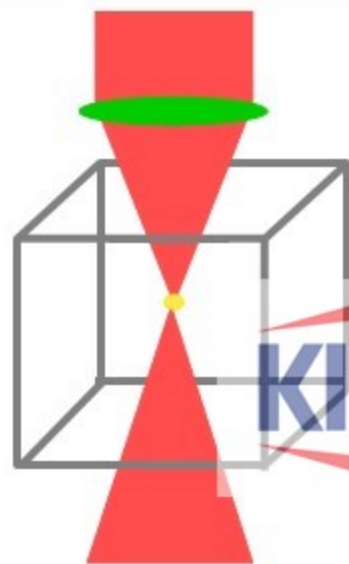
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펨토공정연구실

- Fabrication of grating structures in transparent materials
- Fabrication of waveguide structures in transparent materials

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펄초 레이저 내부 가공 원리



펄초 레이저 펄스 집광

(순간강도: $> 10^{12}$ W/cm²)

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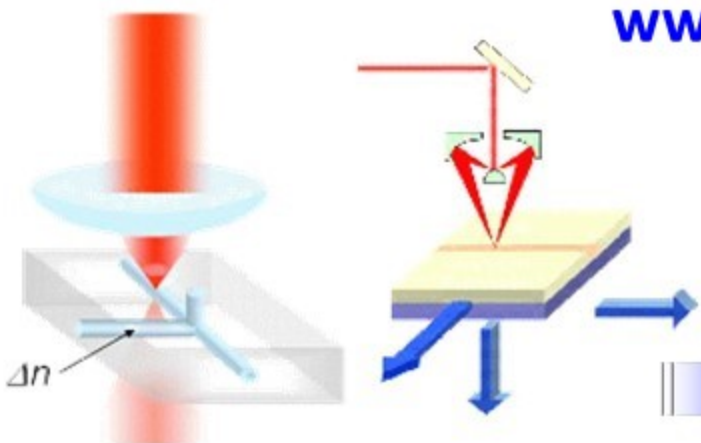
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비선형 광-재료간 프로세스

(저밀도 플라즈마 생성)

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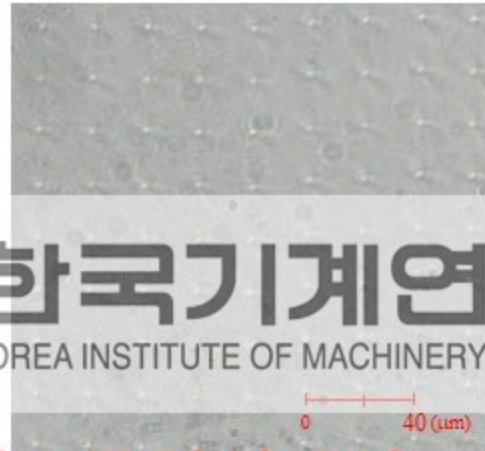
미세공간영역에서 구조변형

(굴절률변형, 홀생성, 보이드생성, 크랙생성)

**미소내부공간 (1 x 1 x 1 (μm)) 에서
프로세스 가능**

Refractive index modification & Optical Cracks

Refractive index modification ($I < \sim 1.5 \times 10^{14} \text{ W/cm}^2$)

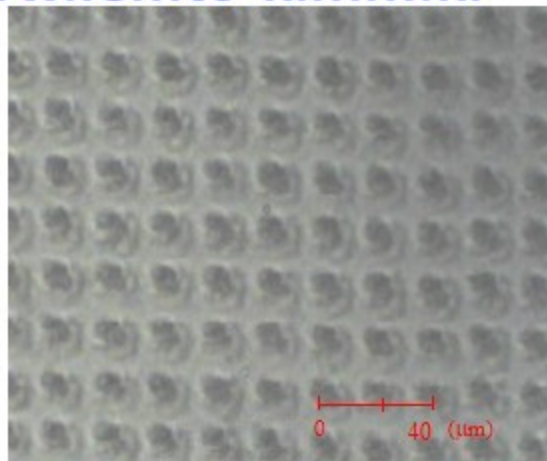
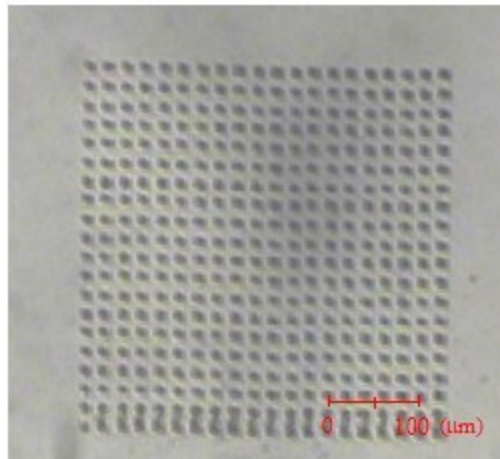


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$I = 5 \times 10^{13} \text{ W/cm}^2$

Optical damage (with Cracks) ($I > \sim 1.5 \times 10^{14} \text{ W/cm}^2$)

펄스공정연구실
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$I = 7 \times 10^{14} \text{ W/cm}^2$

회절격자제작



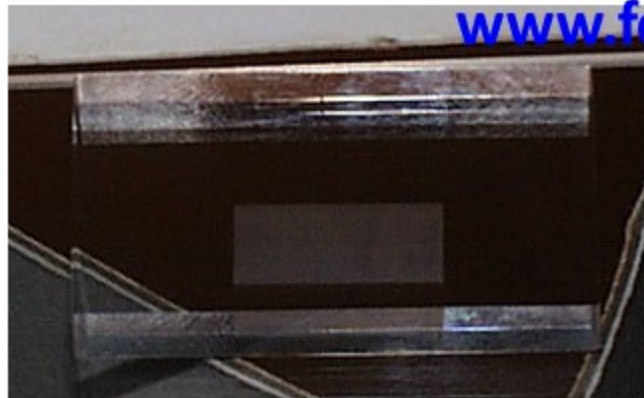
(a) Internal grating



(b) Diffraction image

펨토공정연구실

www.femto-kimm.kr



(a) Internal grating



(b) Diffraction image

Diffraction image

Incident light source
(He-Ne laser)



펨토공정연구실

www.femto-kimm.kr



회절격자제작

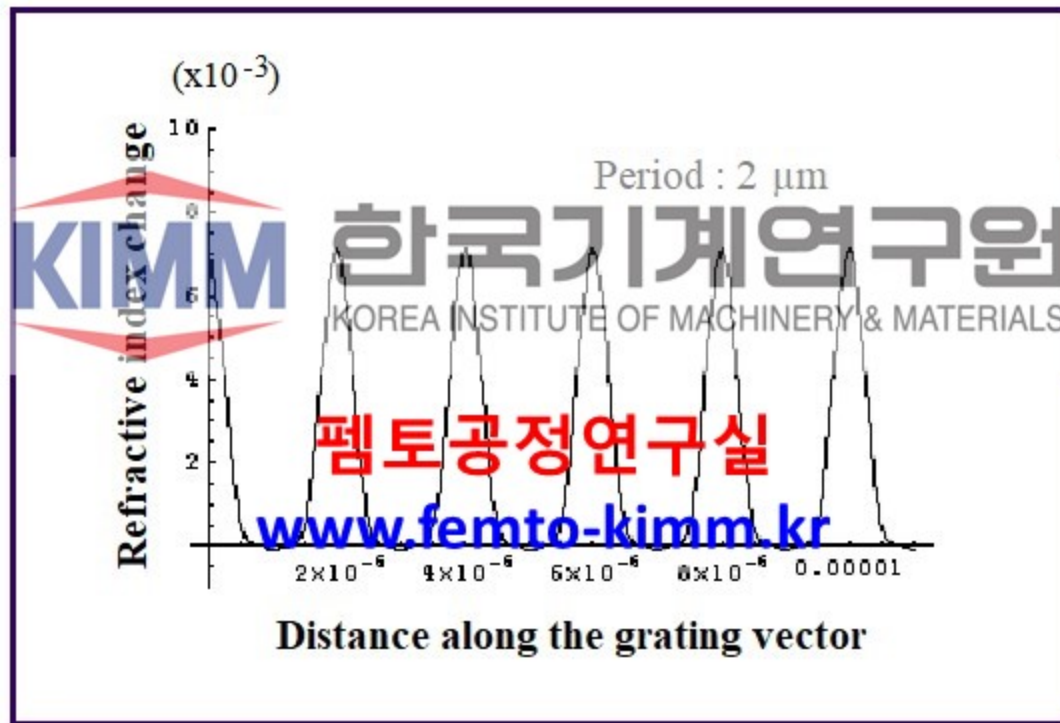


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Variation of the refractive index change



Principle : Transmission diffraction gratings
(From Kogelnik's coupled mode theory)

(Calculated)

Fabrication of optical waveguide



Writing Optical Waveguide

Far-field Pattern

Character writing in transparent materials

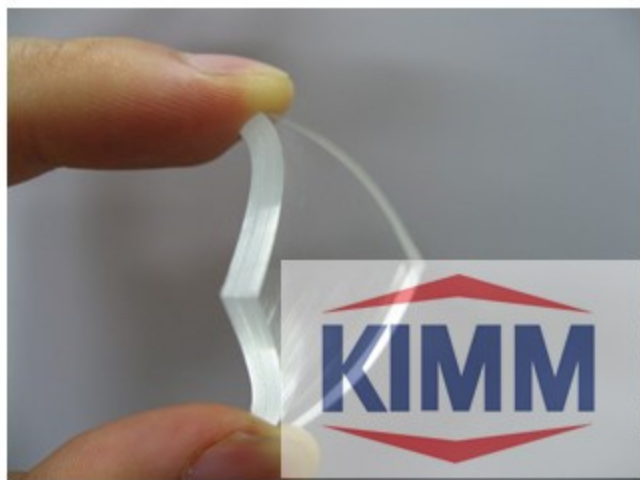


Acryl



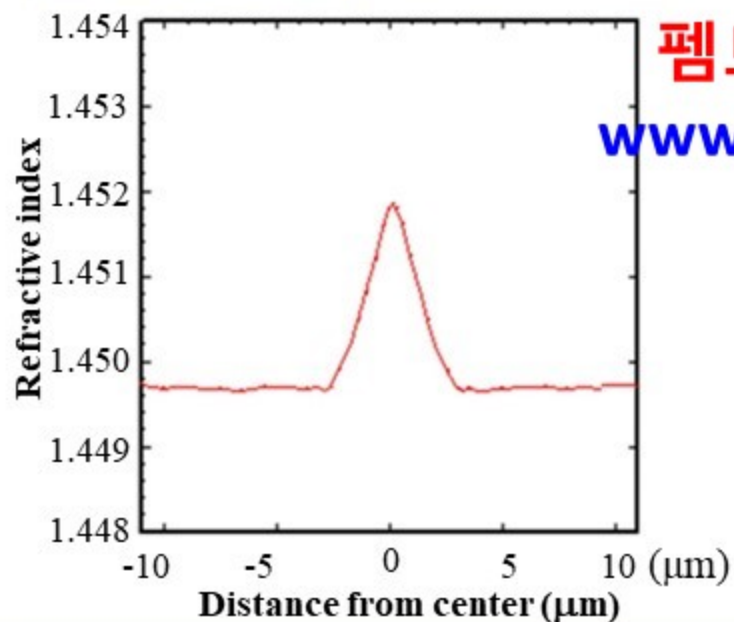
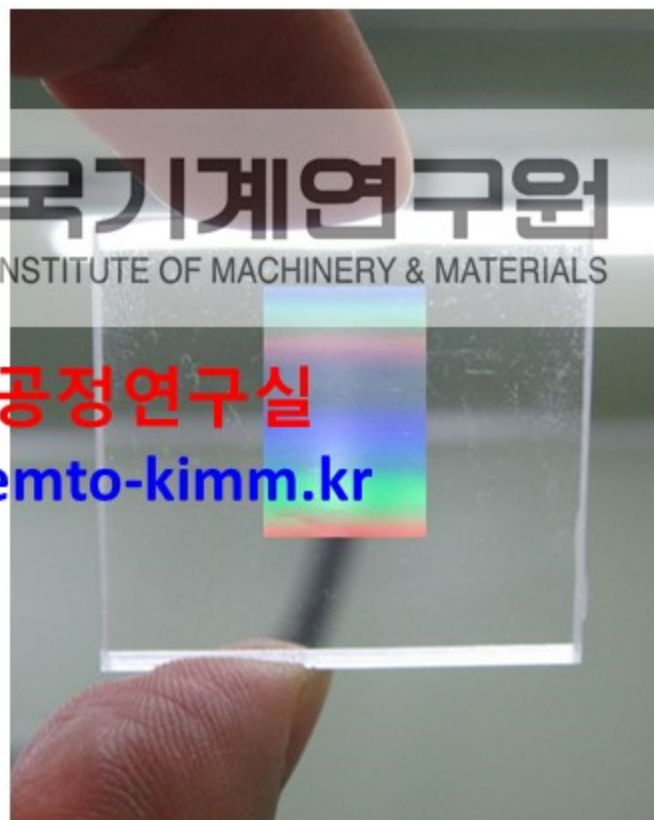
Silica

Femtosecond laser embedded grating micromachining of flexible PDMS plates



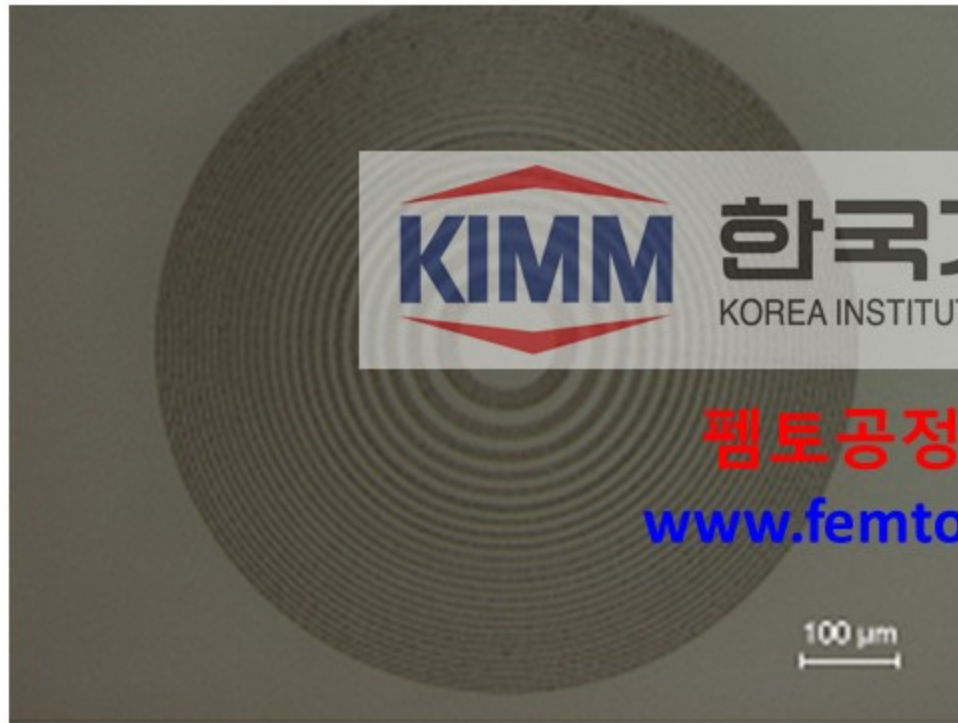
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펨토공정연구실
www.femto-kimm.kr



in press Optics Communications (2009)

Fabricated Fresnel zone plate inside fused silica



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www.femto-kimm.kr

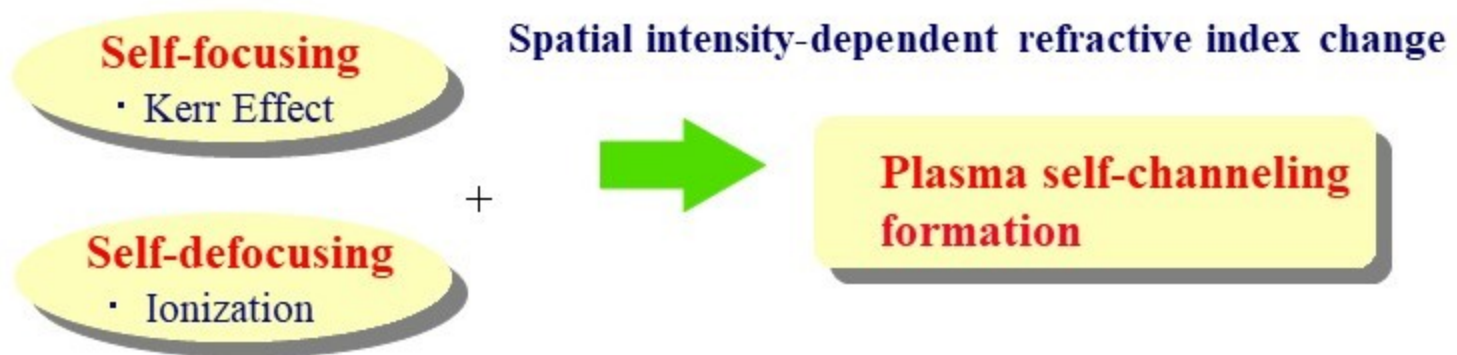
 **Internal processing in optical fibers**
induced by plasma self-channeling
KIMM 한국기계연구원
KOREA INSTITUTE OF MACHINERY & MATERIALS
펨토공정연구실
www.femto-kimm.kr

Plasma self-channeling ?

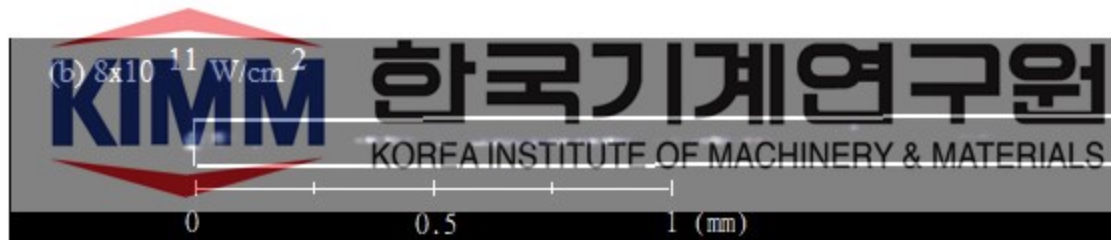
Plasma self-channeling is an **intensity-dependent nonlinear phenomenon**, in which a laser beam is tightly focused and guided for the distance longer than the **Rayleigh range**



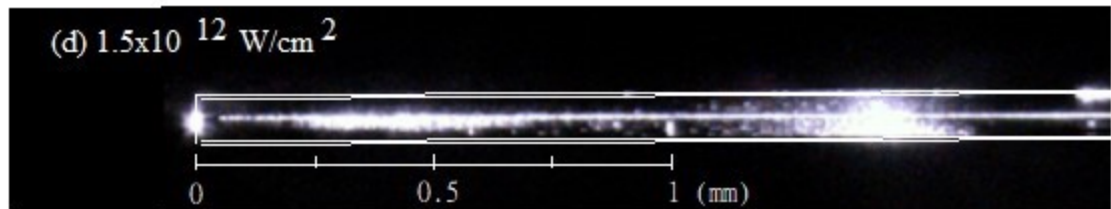
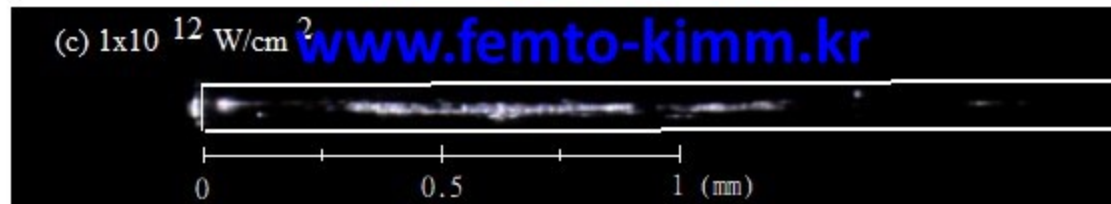
펨토공정연구실
Mechanism of self-channeling
www.femto-kimm.kr



Microscopic side views of plasma channel formation as a function of intensity



펨토공정연구실

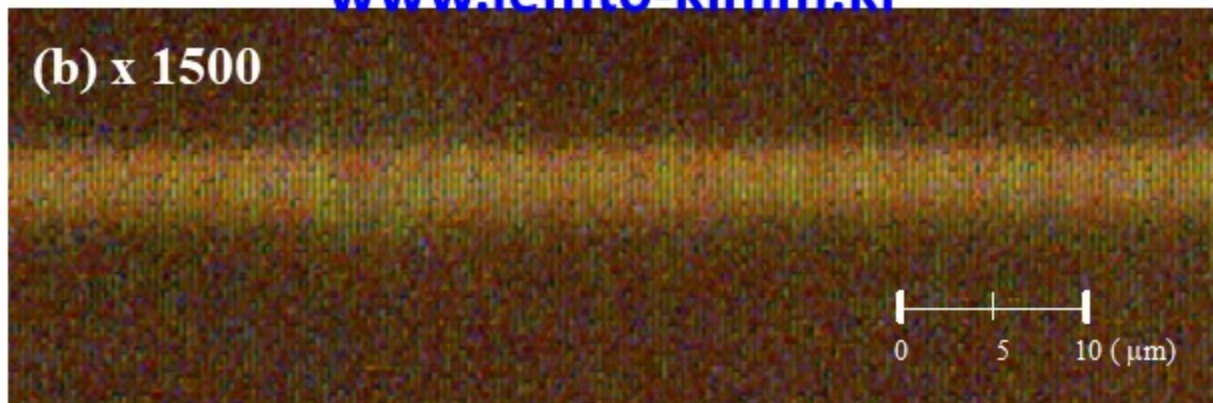


Fabrication of double cladding structure in an optical fiber

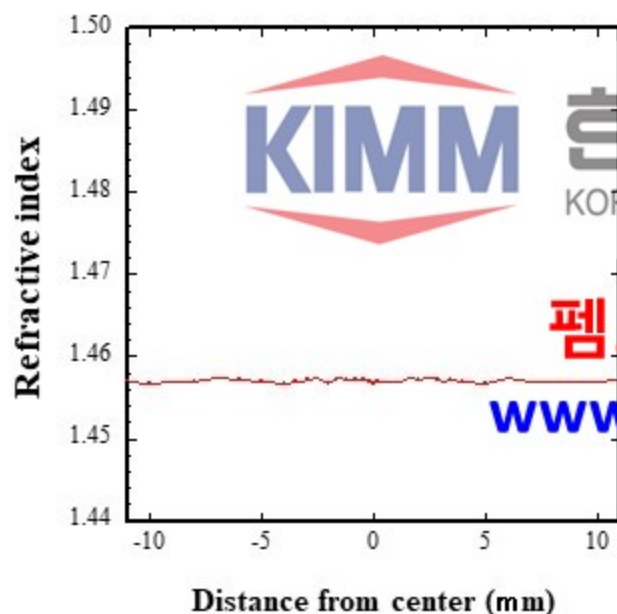


펨토공정연구실

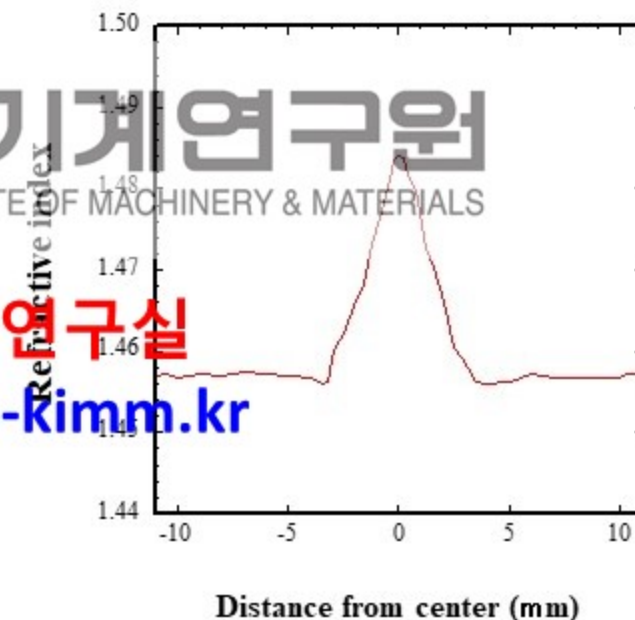
www.femto-kimm.kr



Refractive index profile of induced bulk modification



(a) Before irradiation



(b) After irradiation

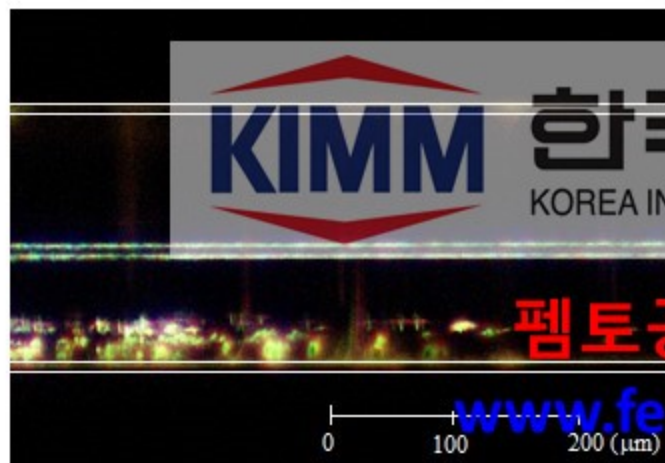
Output intensity profile through multimode fibers



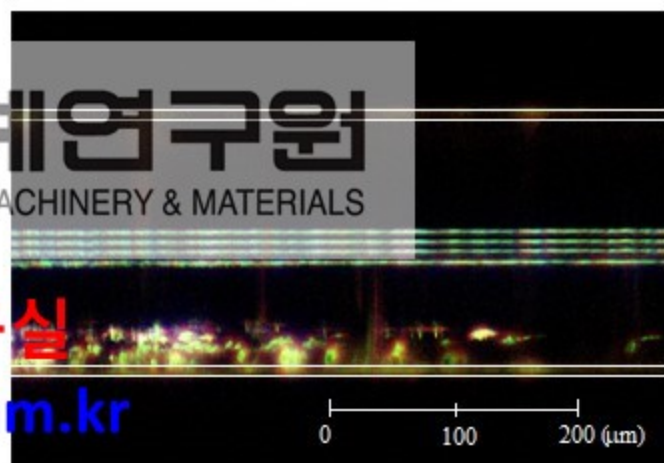
(a) Unmodified optical multimode fiber (100/110 μm core/cladding diameter) (b) Modified optical multimode fiber

Induced refractive index modification provides a double cladding structure in a multimode fiber and serves as a lower-order mode converter from the propagating multimode beams.

Fabrication of multi-core structure in an optical fiber



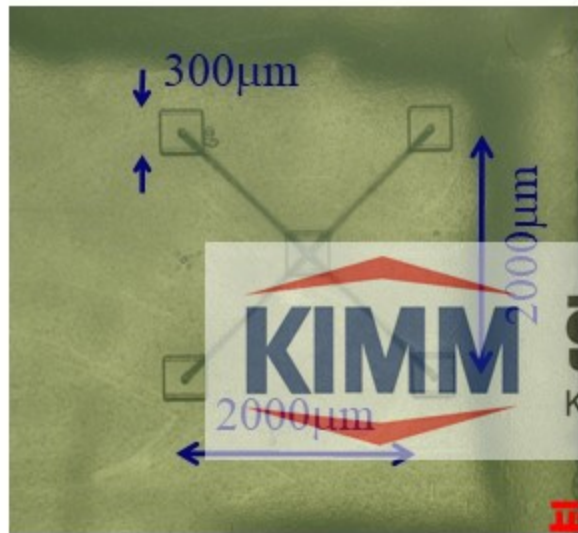
(a) Two core structure



(b) Four core structure

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Three-dimensional micro-machining
of photo-structurable glass
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Fabrication of 3-dimension Microstructure

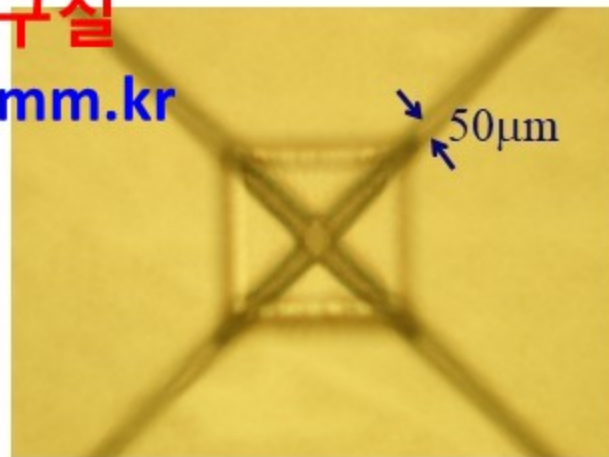
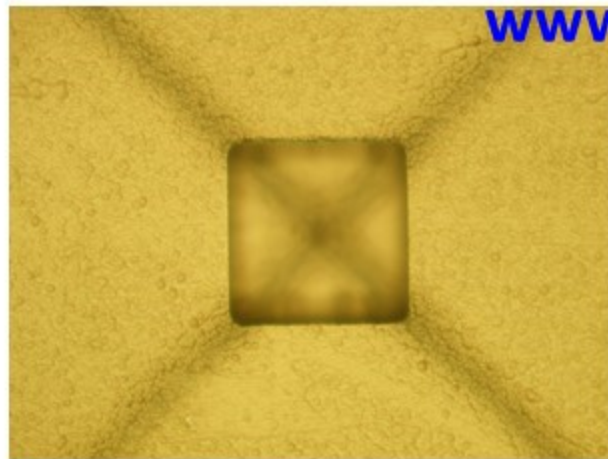


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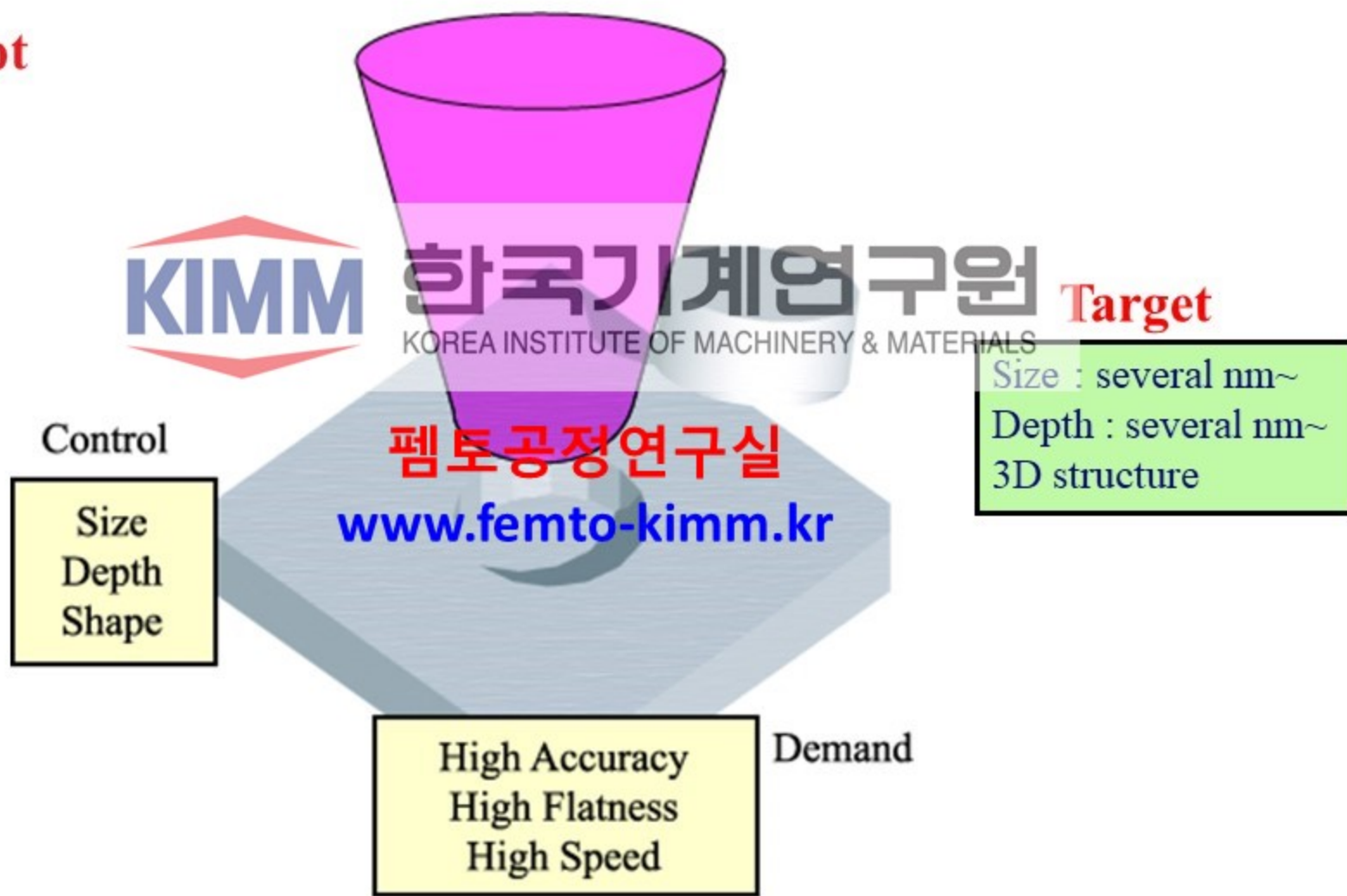
Inside

Co-worker : Dr. Sugioka (RIKEN)

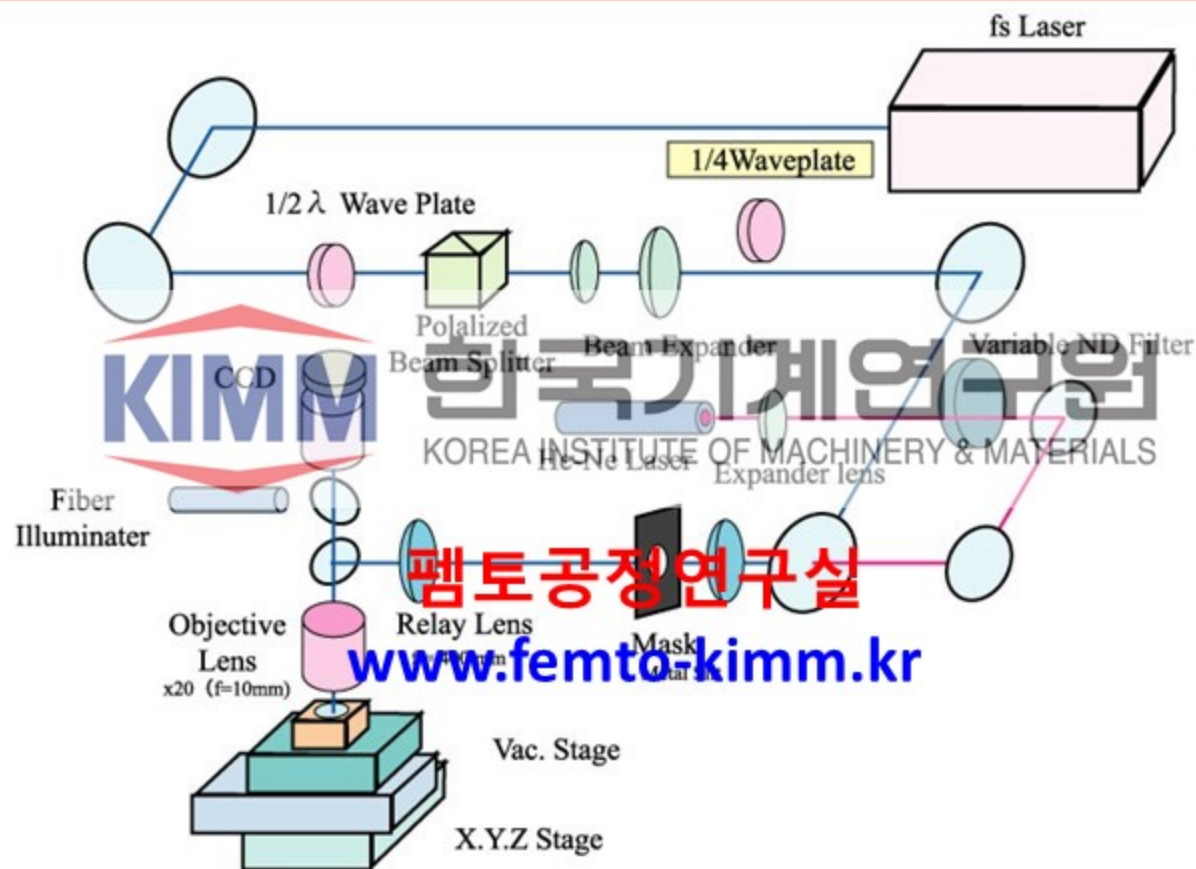
Ultra Precise machining of metals
KIMM 한국기계연구원
KOREA INSTITUTE OF MACHINERY & MATERIALS
with a femtosecond laser
펨토공정연구실
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Femtosecond laser direct processing

Concept



Control technique of nano-micro machining with a femtosecond laser



Procedure Automatic Control by a Computer

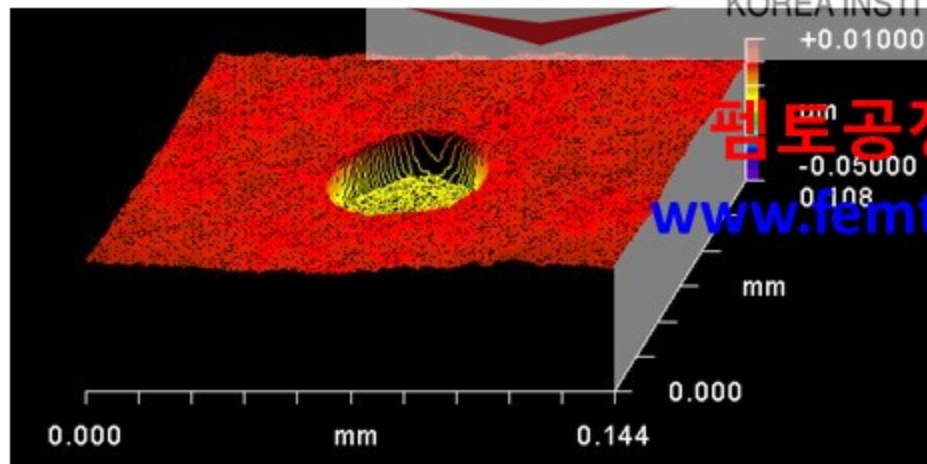
1. Investigation of interaction property between femtosecond laser pulses and targets
2. Control of laser property and its irradiation condition
3. Control of optical X-Y-Z nano-scale stage
4. Additional processings

Precise nano-machining of bulk metals with a femtosecond laser

(Hole and Surface Relief structure)

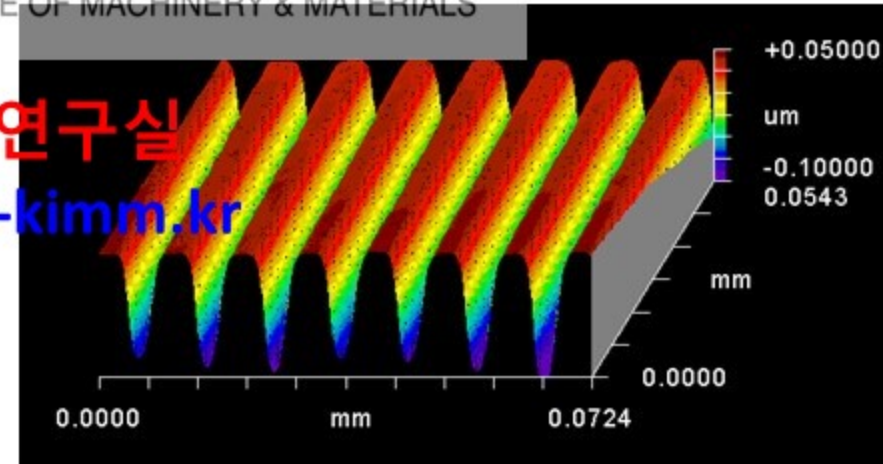
Precise nano-machining on polished metal surface

Bulk Ni
 $\phi 40\mu\text{m}$, 30 nm Depth



Hole (Flat Top) Structure

Bulk Ni
10 μm Pitch, 110 nm Depth



Surface Relief Structure

펄펄초 레이저 : 금속 미세 가공

탄성형 AFM cantilever 제작

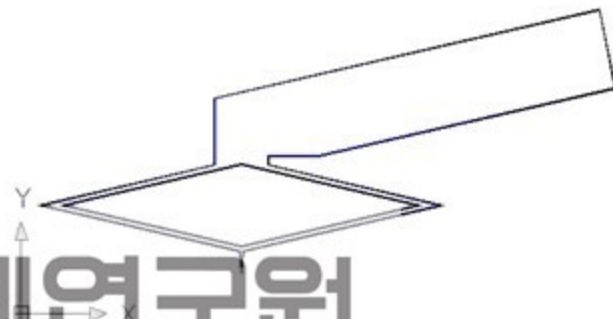
용도: 시료의 기계적 물성 측정용 AFM cantilever

재질: stainless steel (t=50 μm)

실험조건:

100 fs, 1 kHz, 790 nm, scan speed-1mm/sec,

peak intensity- 3×10^{12} W/cm²



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ns Nd-YAG LASER VS Femtosecond LASER

ns Nd-YAG LASER



Femtosecond LASER



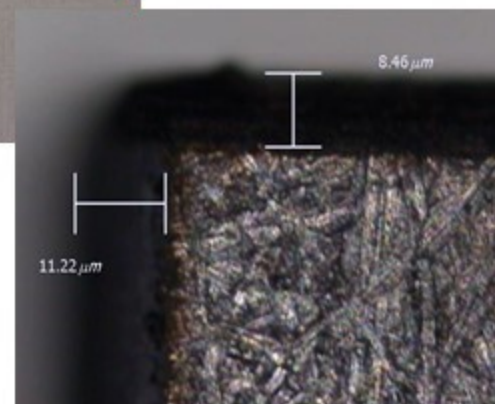
▶ 펨토초 레이저 : 금속 미세 가공

재질: 텅스텐 W (t=500um), 알루미늄 Al(t=500um), Al(t=1mm)

용도: 3차원 고해상 MRI (자기공명영상장치)의 자기발생소자



한국기초과학지원연구원
KOREA BASIC SCIENCE INSTITUTE



Hole drilling on transparent materials



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Hole drilling on sapphire using laser ablation



(a) Surface



(b) Inside

Irradiation condition:

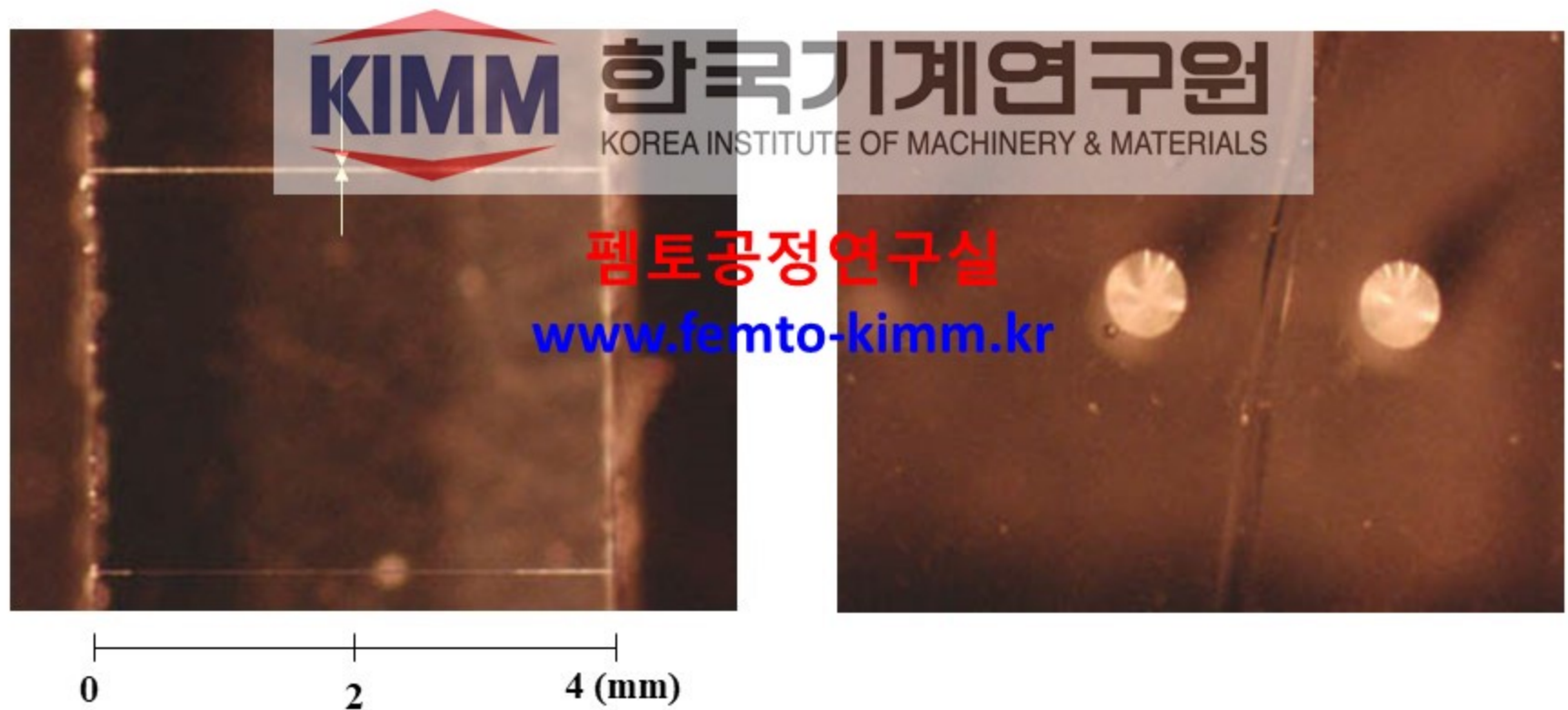
(f:150 mm, P: 380 mJ/Pulse, Rep:1kHz, Irradiation time: 10 sec)

Length of Hole : 250 mm

Aspect rate : 17:1

Hole drilling on Silica Plates

Process : Internal modification + Chemical etching



Hole drilling on Ruby

Process : Internal modification + Chemical etching



Laser cutting of CVD Diamond

Diamond substrate



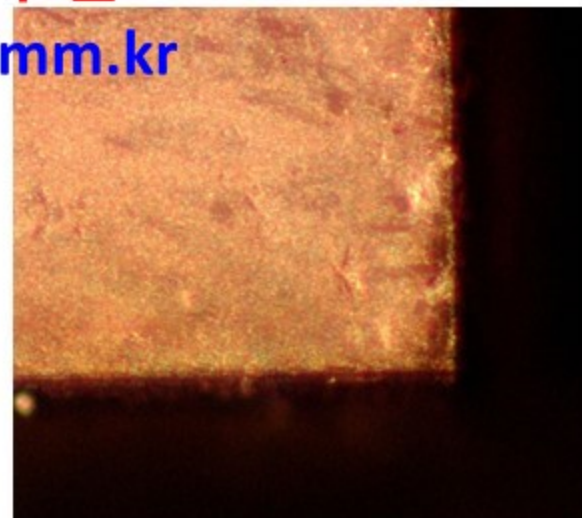
Magnified edge area

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0 200 (μm) **펄스공정연구실**

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Cutted diamond plate



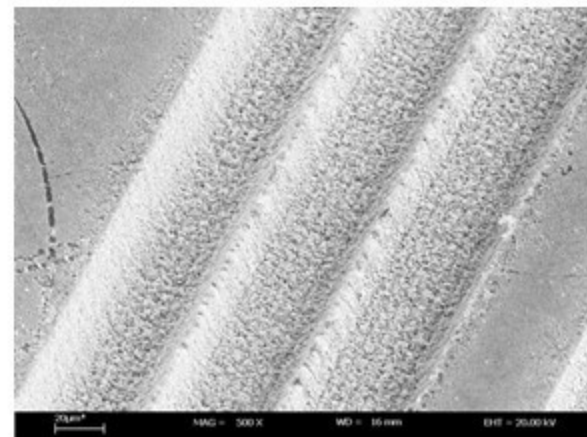
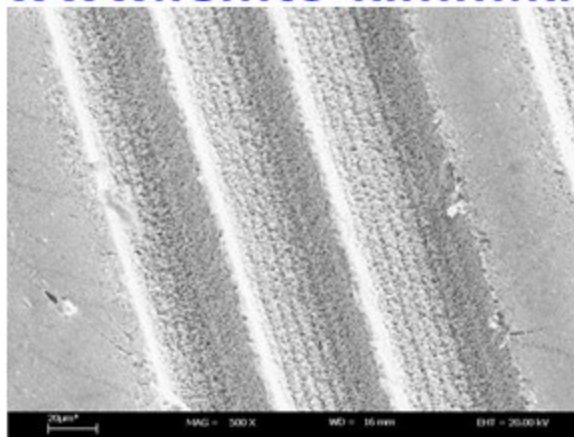
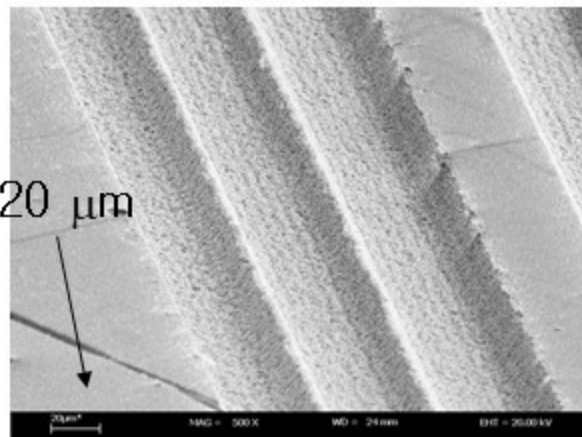
Magnified edge area

Surface Material Processing

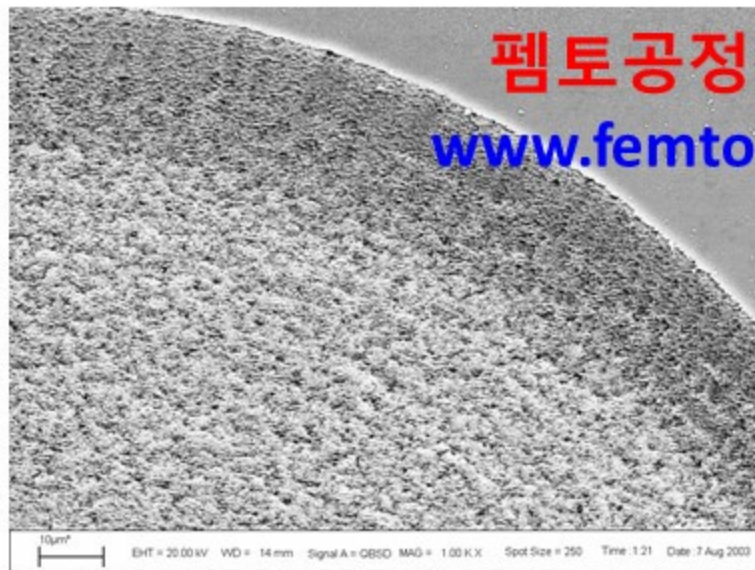
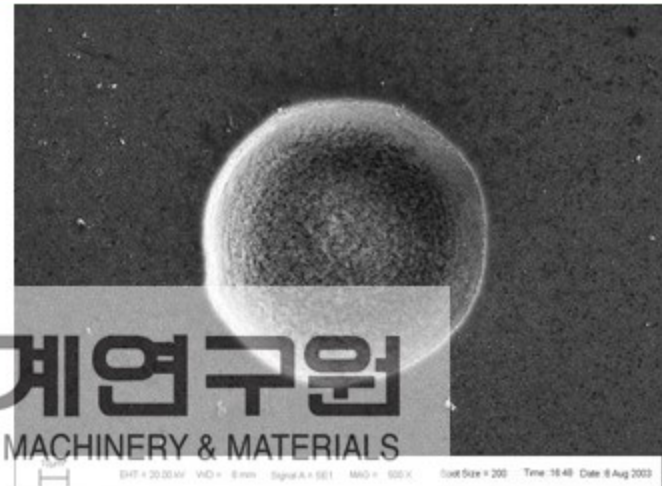
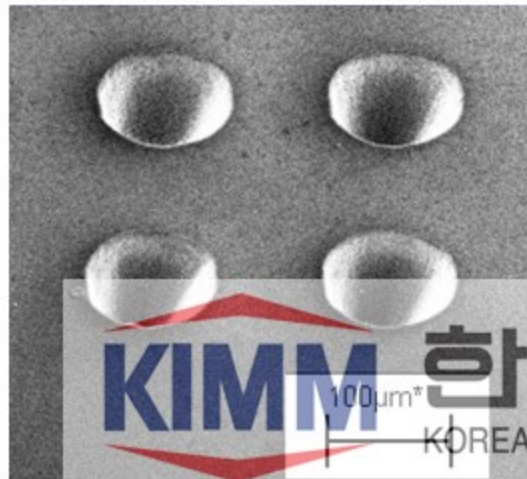


펨토공정연구실
www.femto-kimm.kr

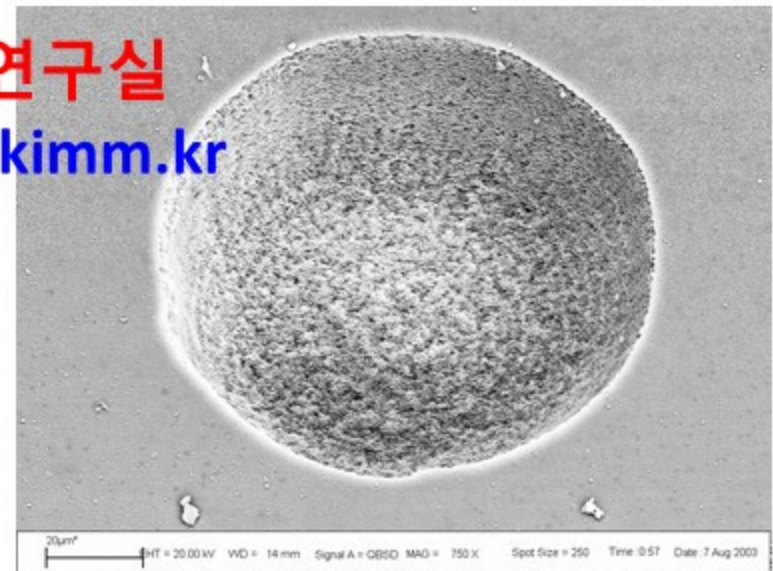
Glass micromachining (soda lime glass)



Glass micro-hole micromachining



300 μm hole



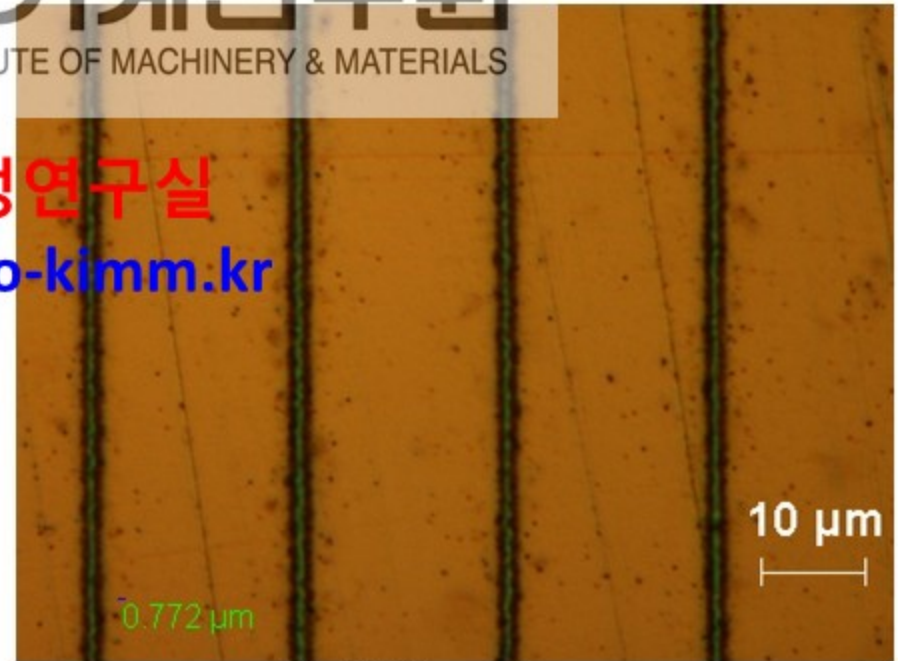
100 μm hole

박막가공 [Al + glass(t:250nm)]

Glass + Al(250nm)



V: 0.02mm/s
Pulse power: 19uW



V: 0.02mm/s
Pulse power: 310uW

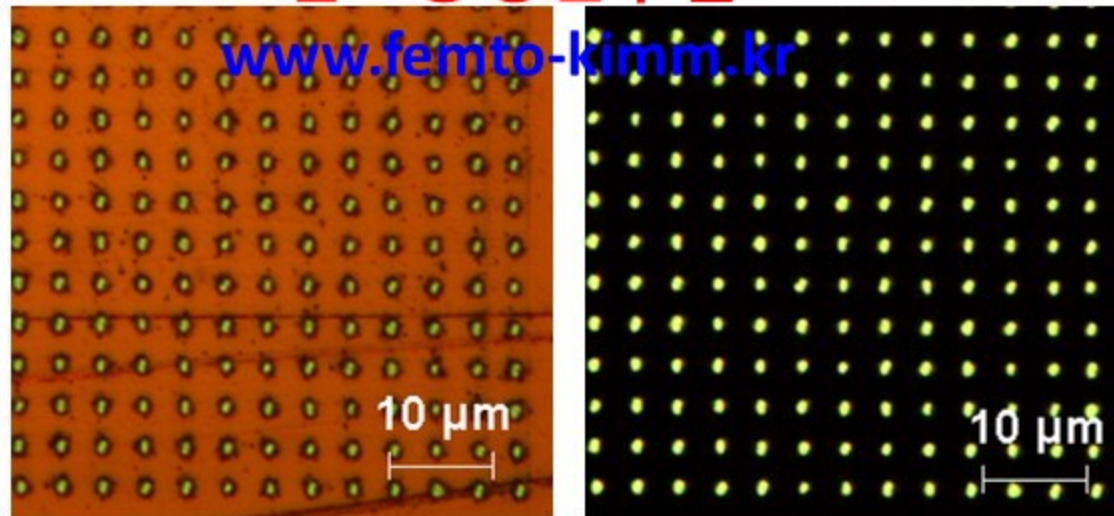
Front



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Back



Glass + Al(250nm)



삼성전자



한국기계연구원

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10 μm

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서터 15ms_피치 2.5 μm

10 μm

디스플레이 가스주입 부품 노즐 형상가공

의뢰기업명 : 삼성SDI



SAMSUNG SDI



펨토공정연구실

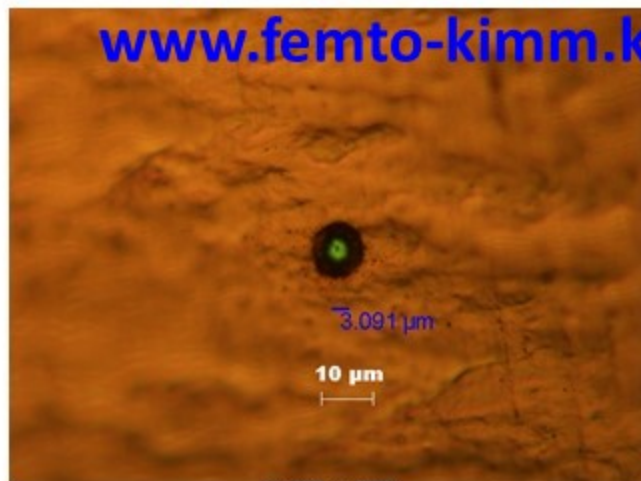
www.femto-kimm.kr

홀 직경 : 3um

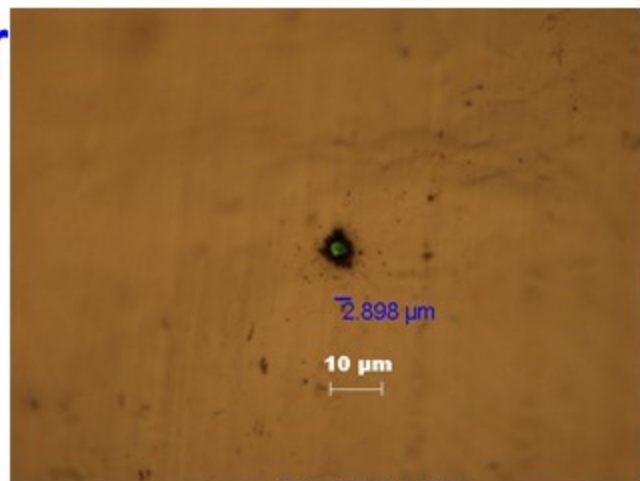
두께 : 25um

재료 : SUS

Aspect Ratio: 8



INPUT



OUTPUT

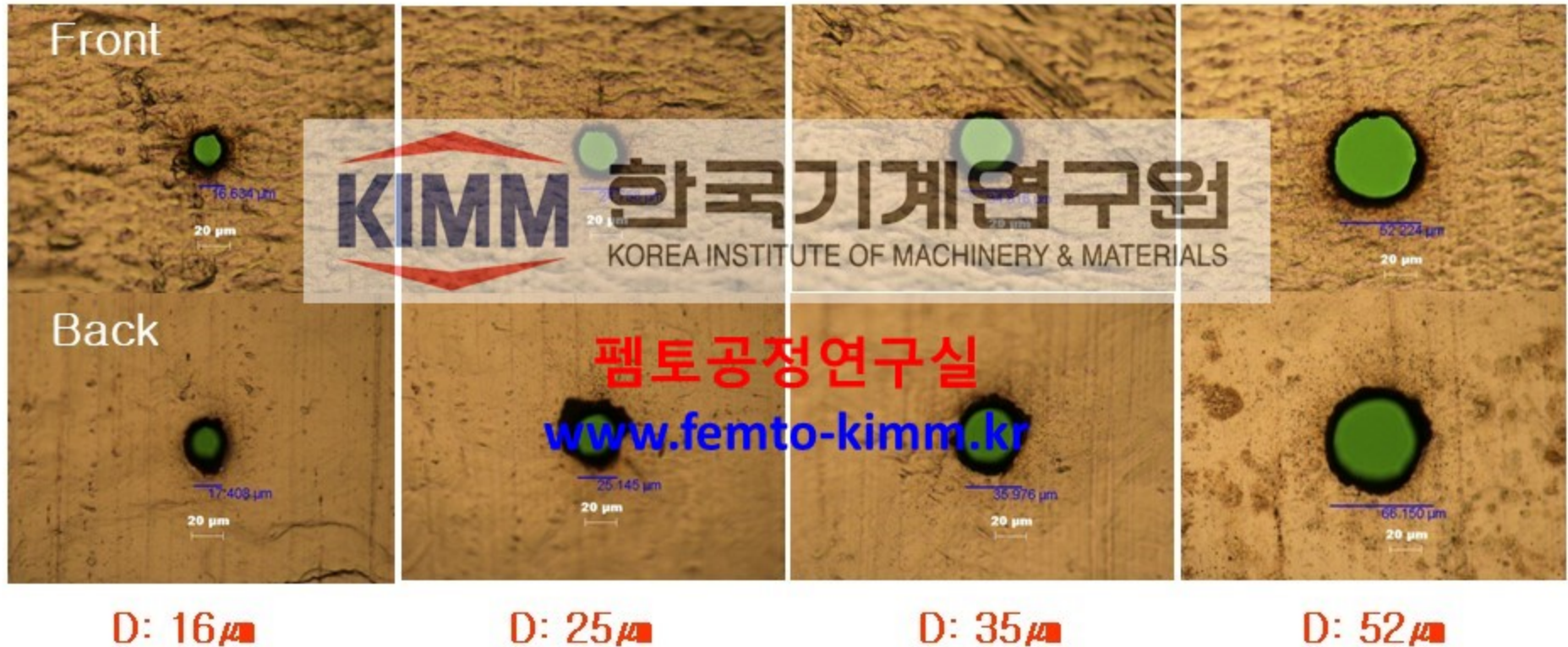


D: 4 μm

SAMSUNG SDI

박막가공 [AlO50 (t:20~25 μm)]

Objective :50X



SAMSUNG SDI

기어 형상 가공

재료:
세라믹



부산대학교
PUSAN NATIONAL UNIVERSITY

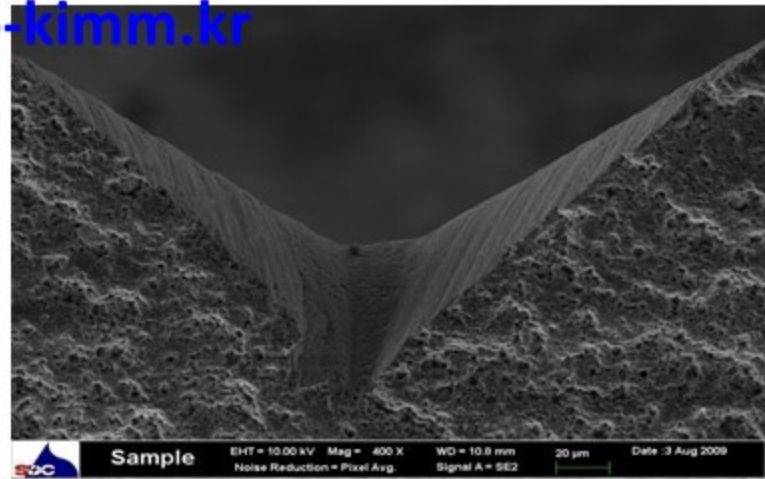
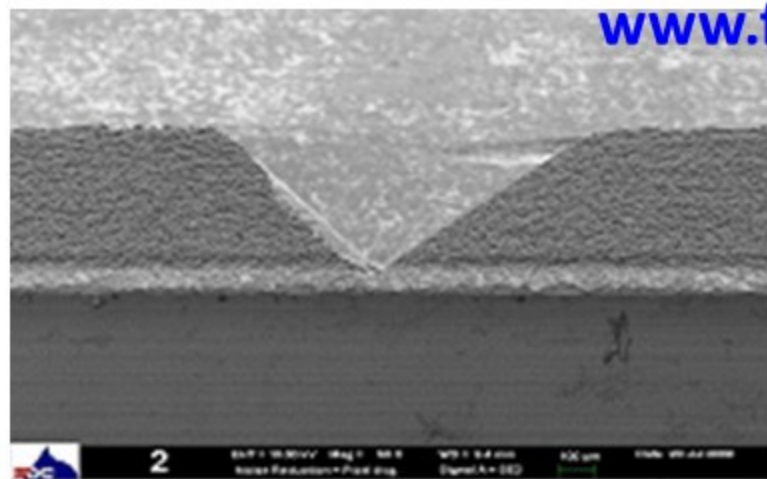
국가핵심연구센터 (NCRC)

실험목적 : 기존 Wire Cutting 방식은 Wire 방전열에 의한 Damage가 발생



펨토공정연구실

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Hole control: 2 – 30 um

Hole depth control

열적손상 무

Debris 발생 무

[070402] Femtosecond FT report_한국기계연구원_유기영D.pdf - Adobe Reader

파일(F) 편집(E) 보기(V) 문서(O) 도구(T) 창(W) 도움말(H)

11 / 11 74.2%

4-3. NVM Images (Pattern) Samsung Electro Mechanics

NanoSystem
KIMM 한국기계연구원
KOREA INSTITUTE OF MACHINERY & MATERIALS

Time: 0:00:00
Start: 09/10/2011 10:00:00
Date & Time: 09/10/2011 10:00:00
Mode: High Accuracy Mode

3D image

X Dir. Profile

Roughness
Ra: 2.02 um
Rq: 3.97 um
Rz: 26.93 um
Rt: 2.99 um
Rv: 23.64 um
Rw: 11.16 um

Information
AH: 15.612 um
AW: 225.390 nm

www.femto-kimm.kr

11

고 에너지 분해능 자기 양자 센서 요소 가공
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KOREA INSTITUTE OF MACHINERY & MATERIALS

펨토공정연구실
KIMM 한국기계연구원 **KRISS** 한국표준과학연구원 **공동연구**
www.femto-kimm.kr

자기양자센서 제작 기술 [한국표준과학연구원 요소부품]

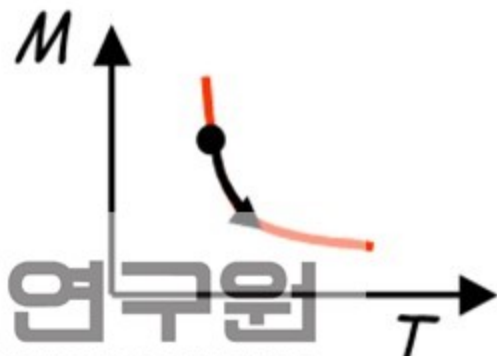
• 금속상자성: Au:Er
 -200 ~ 1000 ppm Er doped in Au

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KOREA INSTITUTE OF MACHINERY & MATERIALS

자화 온도 의존성

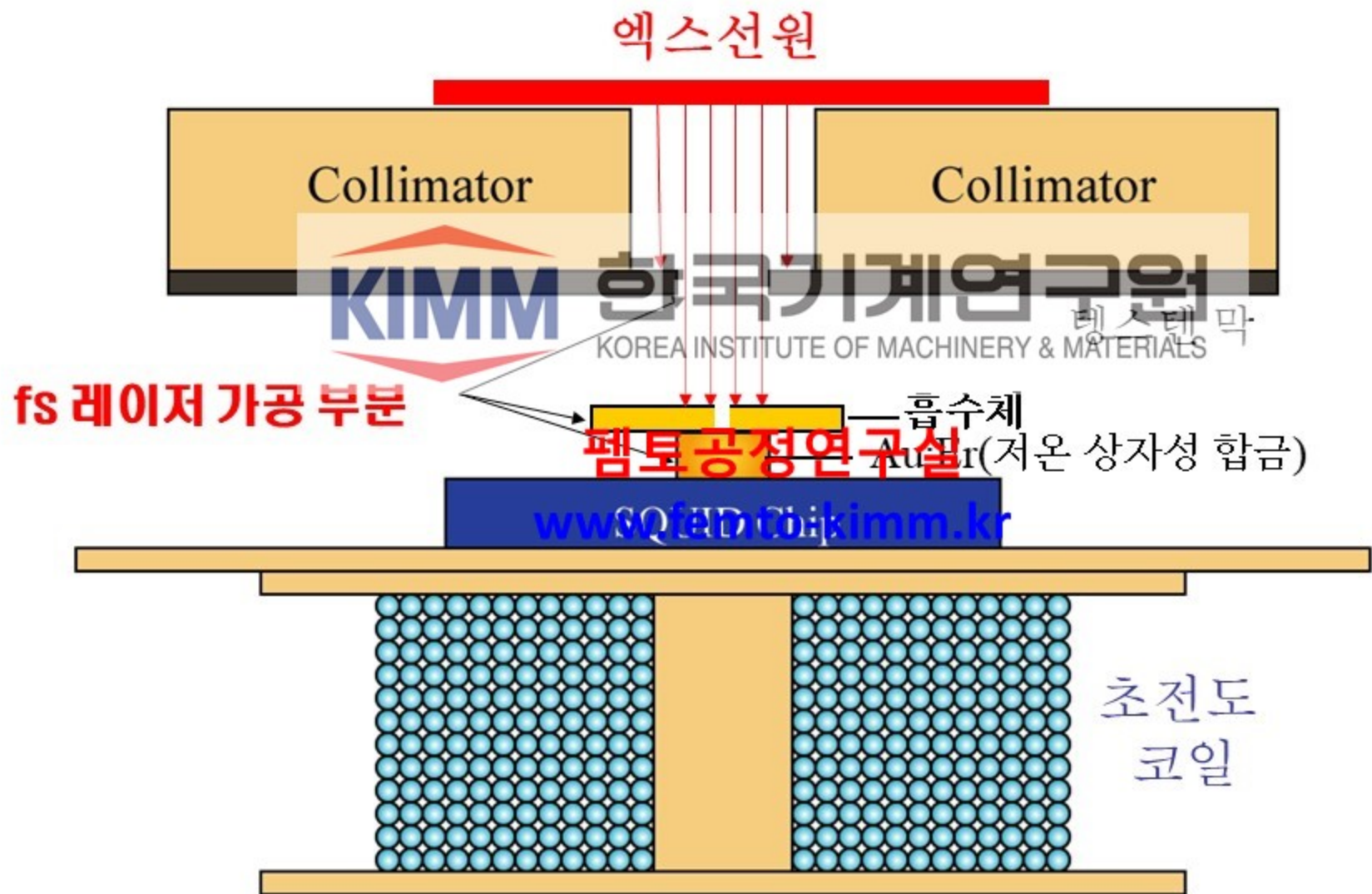


$$E \rightarrow \Delta T \rightarrow \Delta M \rightarrow \Delta \Phi$$

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KRISs 한국표준과학연구원 공동연구

저온 검출기 개략도 (한국표준연 제공)

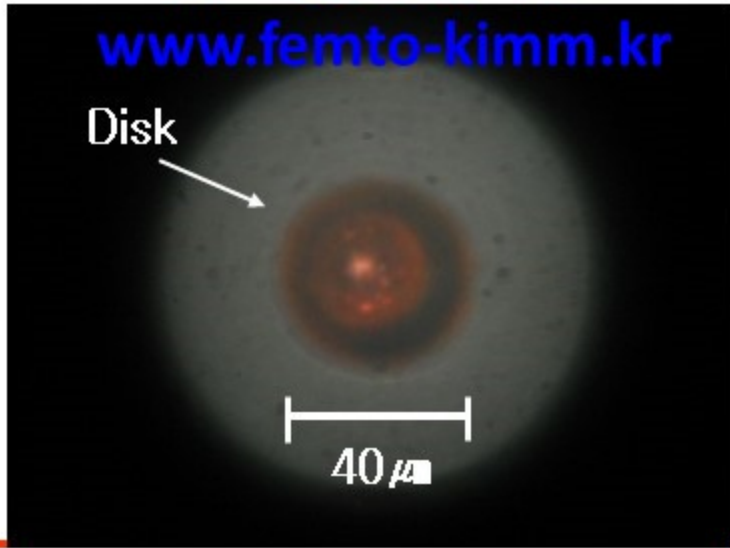


센서박막가공 [Au + Er (t:25 μm)]

Objective :50X



펨토공정연구실



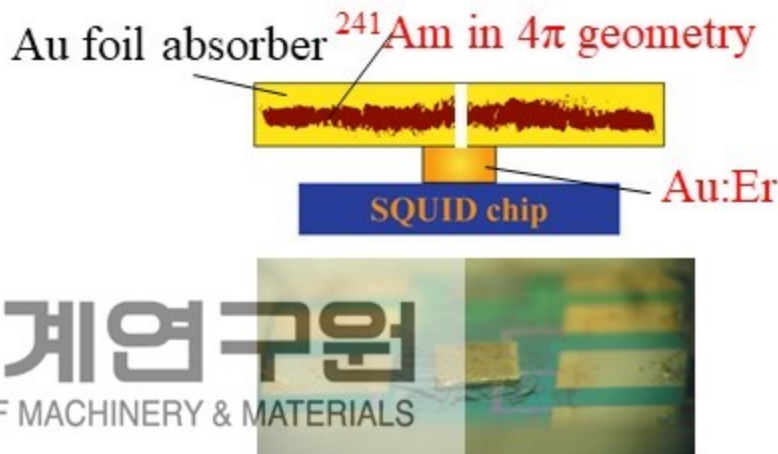
자기양자센서 제작 기술 [한국표준과학연구원 요소부품]

절대방사능측정 (에너지(Q), 선량)

- 일체형(소스 = 검출기)
- 에너지 또는 선량의 손실 없음
- 고 에너지 분해능 측정
- 미량방사선량 측정
- 방사 화학 전처리 불필요

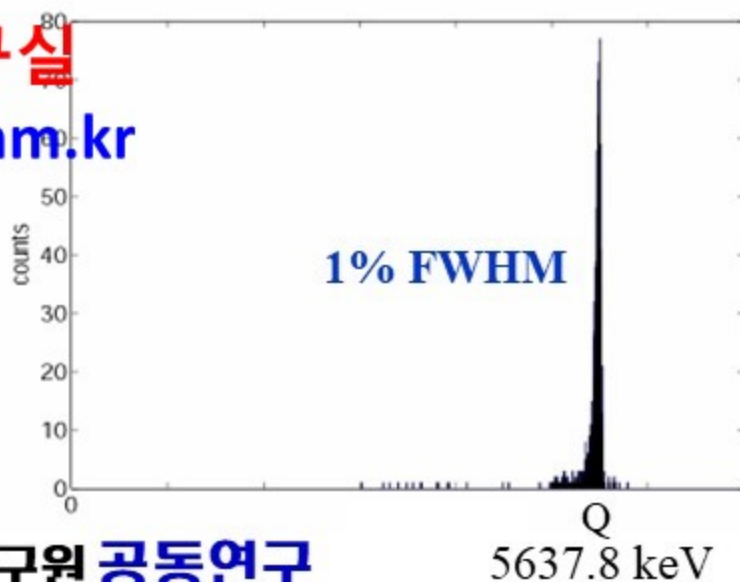


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100% 측정 효율
배경 잡음 없음
고분해능 실현



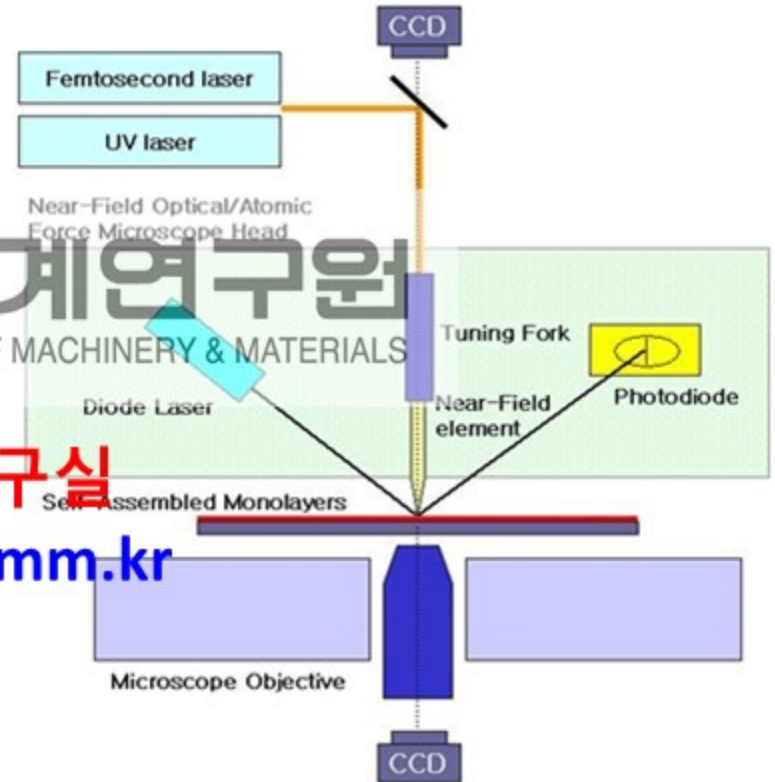
Surface Material Processing



using NSOM
펨토용정연구실

www.femto-kimm.kr

NSOM lithography



Resist: **Organic molecules** (DDT, ODT, HDT...)

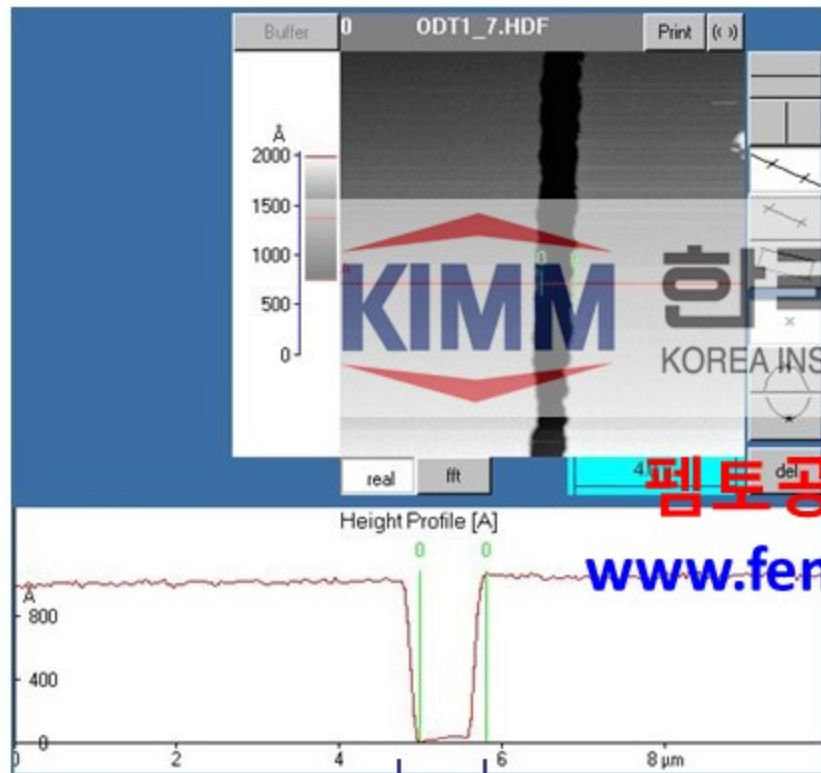
Tip: **Nano-pipet**

Aperture-sample ~ 10 nm

Femtosecond laser: 800 nm

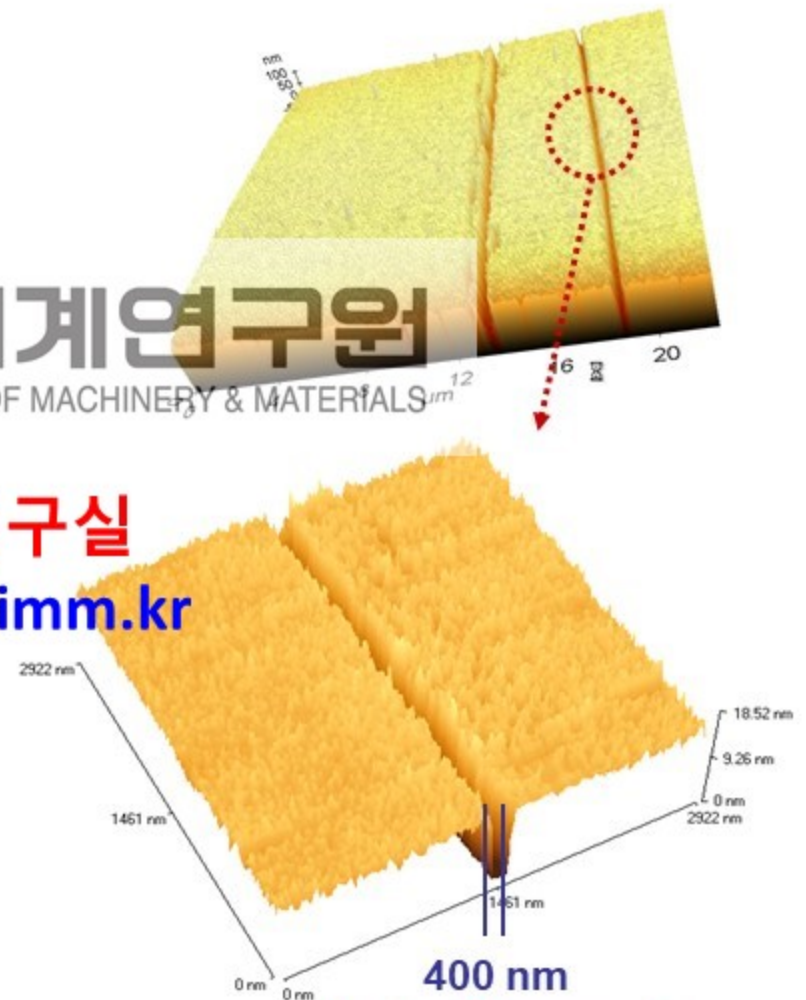
장원석박사(KIMM)

Thin Gold Film Patterning



800 nm

Using Lens Focusing



Using Nanoprobe

펄토초 레이저 응용 생체세포 조작 및 진단기술 개발
KIMM **한국기계연구원**
KOREA INSTITUTE OF MACHINERY & MATERIALS

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www.femto-kimm.kr

연구내용:

Femtosecond laser nano bio application - living cell manipulation

Femtosecond pulses (probe)

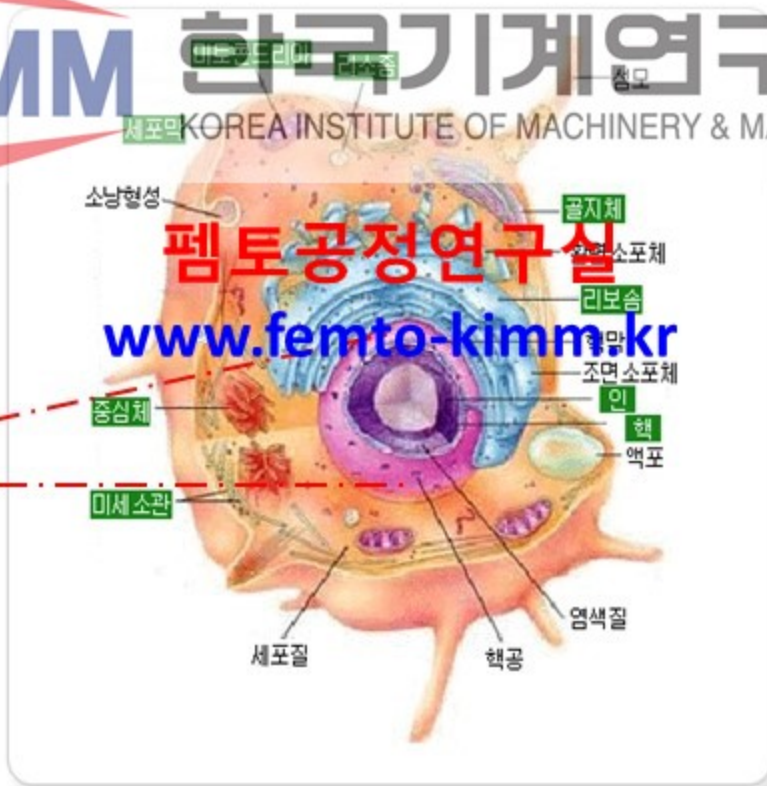
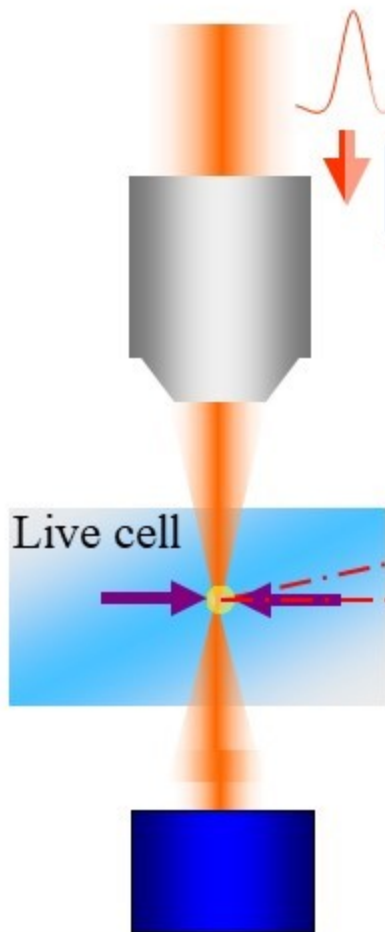
펨토초 광펄스 특성 제어

: 에너지, 파장, 주파수, 위상, 편광, 펄스수, 펄스폭, 파워 등
물성측정 파라메타

: 흡수, 반사, 산란, 투과, 굴절, 회절, 밀도 등



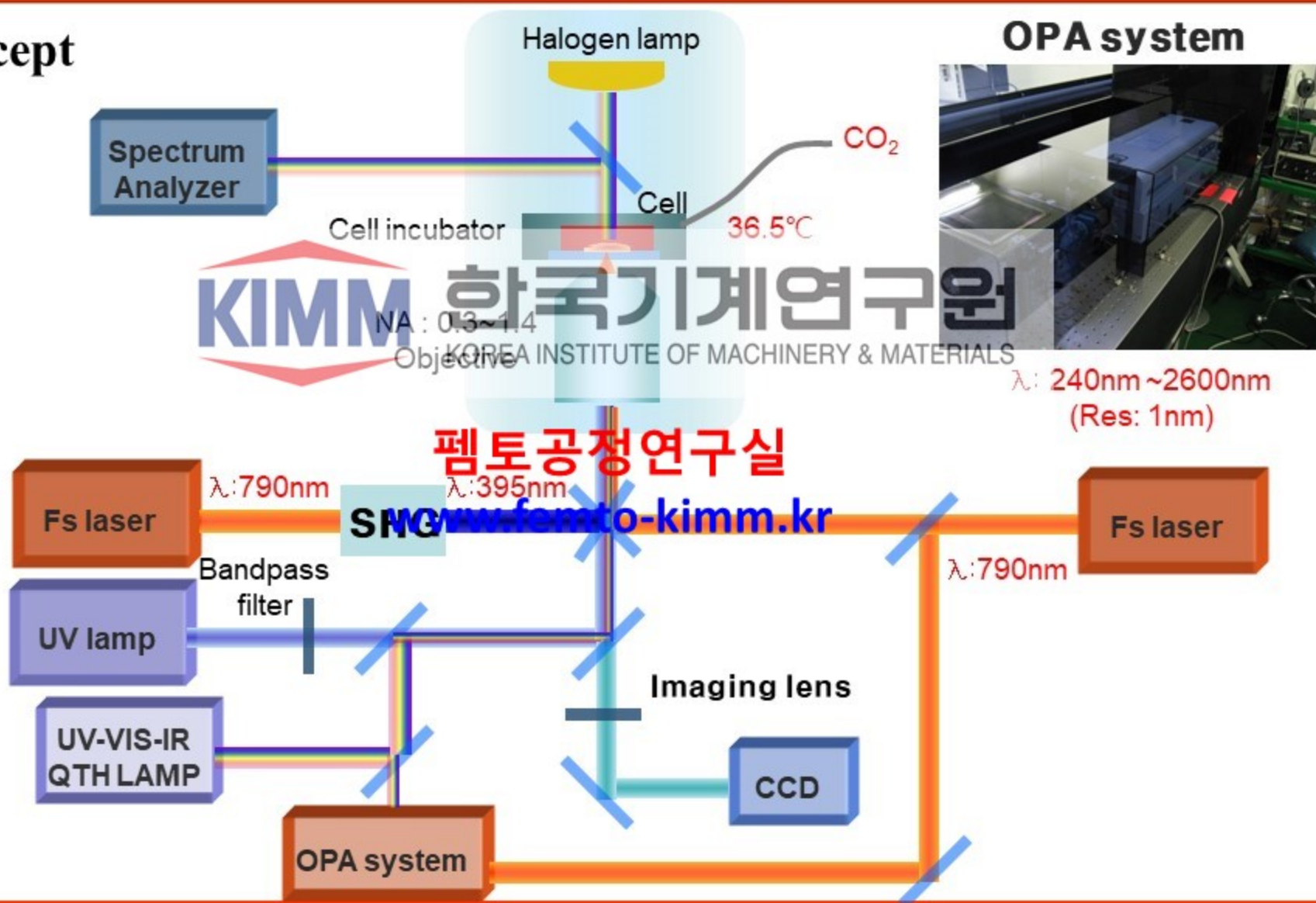
특징



- 비접촉, 비침수성
- 집광 영역 세포 및 주변 세포 비손상
- 폭 100nm 까지 집속 (self-focusing)
- 3차원 물성 정보
- 세포 내 소기관 물성 정보 실시간 관측

펨토초 레이저 기반 단일 생체 세포 나노 수술/진단기술

Concept



펨토초 레이저와 생체세포 상호작용

fs laser Energy vs. Photo-disruption of live cell

Before

After



NIR Femtosecond laser irradiation (@790nm)

HMEC (Human Mammary Epithelial Cell)

● *in vitro* 세포 물성 계측 및 세포, 세포소내기관 조작 원천기술 확보 [fs기술]

Cancer cell (MDA-MB-231)
Histone H2B GFP transfection

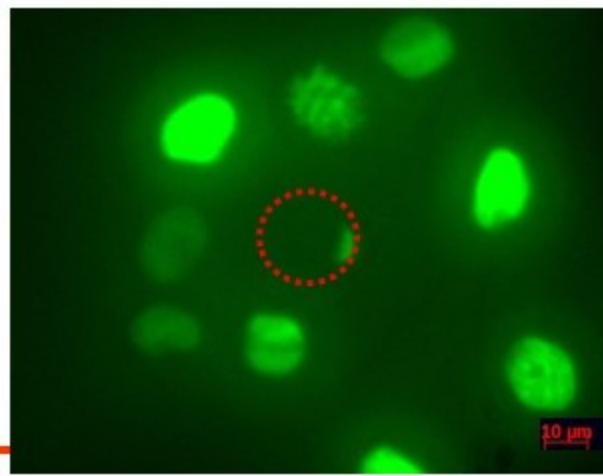
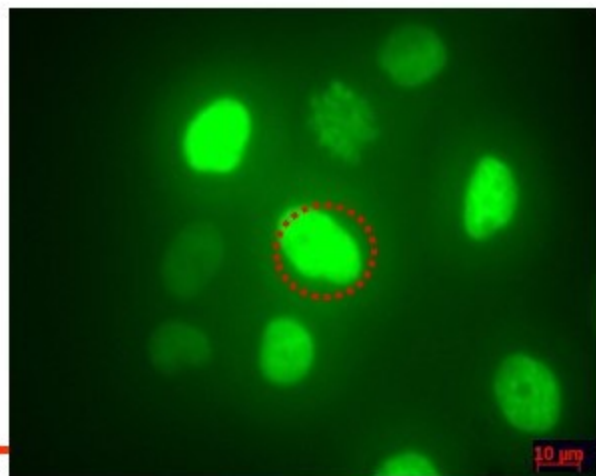
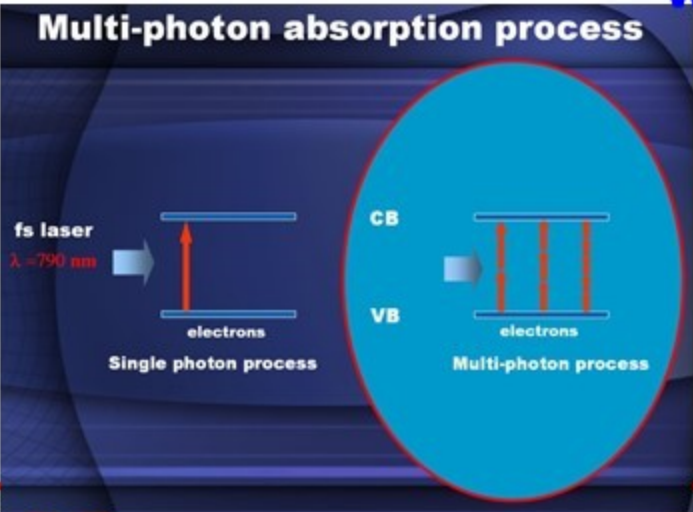
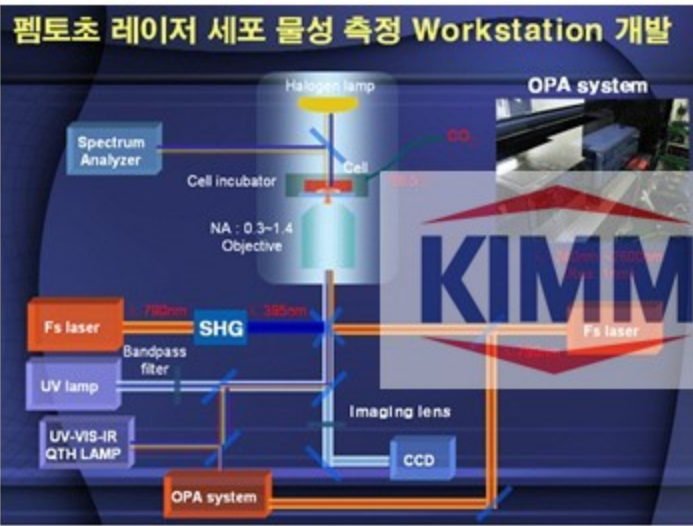
Before fs irradiation

After fs irradiation



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생체 세포 내 미토콘드리아 광제거 연구

세포명: human glioma U87MG DNA 명: pEYFP-Mito plasmid



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10 μ m

생체 세포내 미토콘드리아 제거 (Before fs irradiation)

세포명: human glioma U87MG

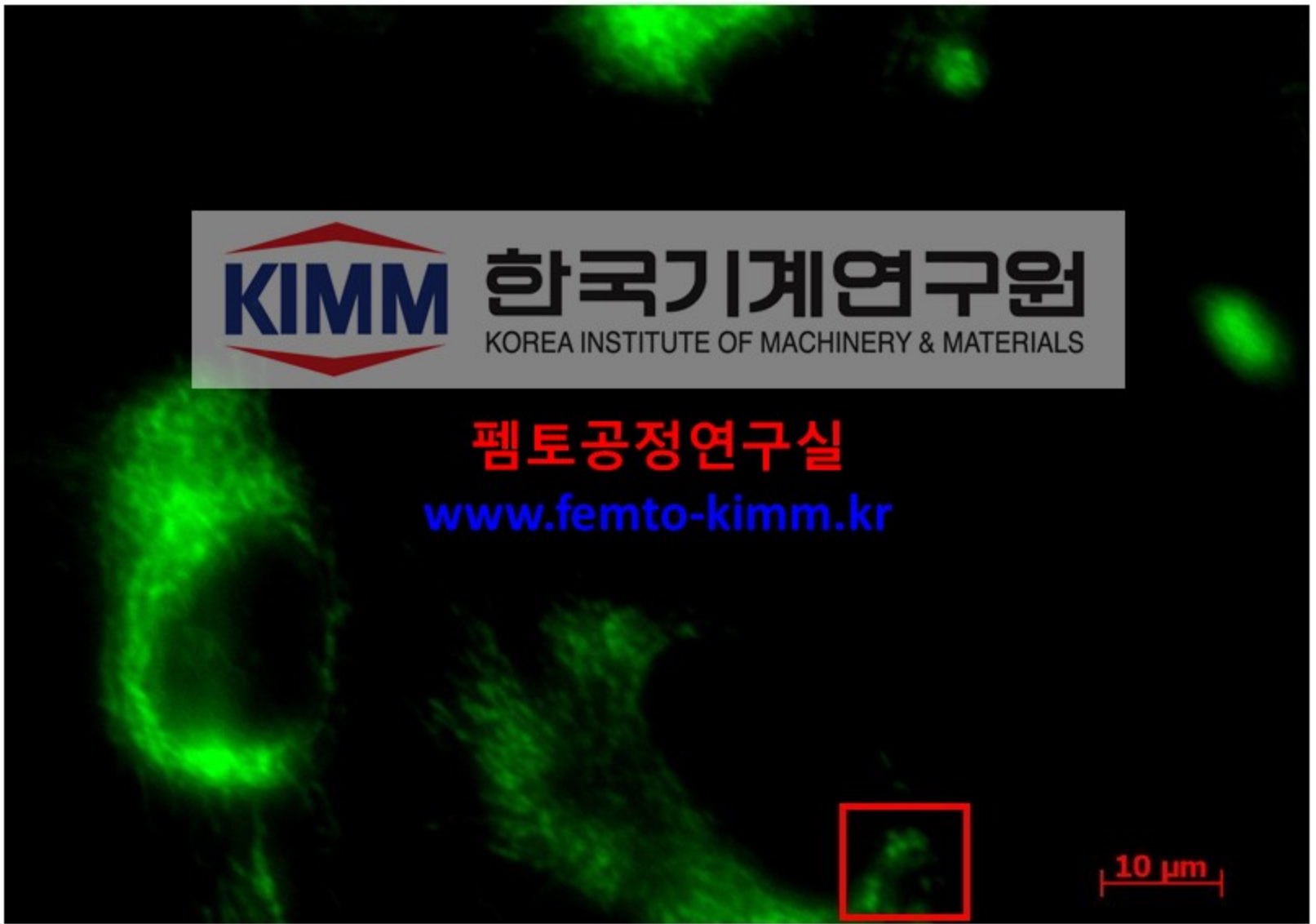


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10 μm



생체 세포내 미토콘드리아 제거 (After fs irradiation)

세포명: human glioma U87MG



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10 μm

생체 세포내 미토콘드리아 제거 연구

세포명: human glioma U87MG

Before fs irradiation

After fs irradiation



0 10 μm

0 10 μm

생체세포 선형흡수(UV영역) 특성 연구

실험 적용 세포

연구결과

Types of Human Breast Cells

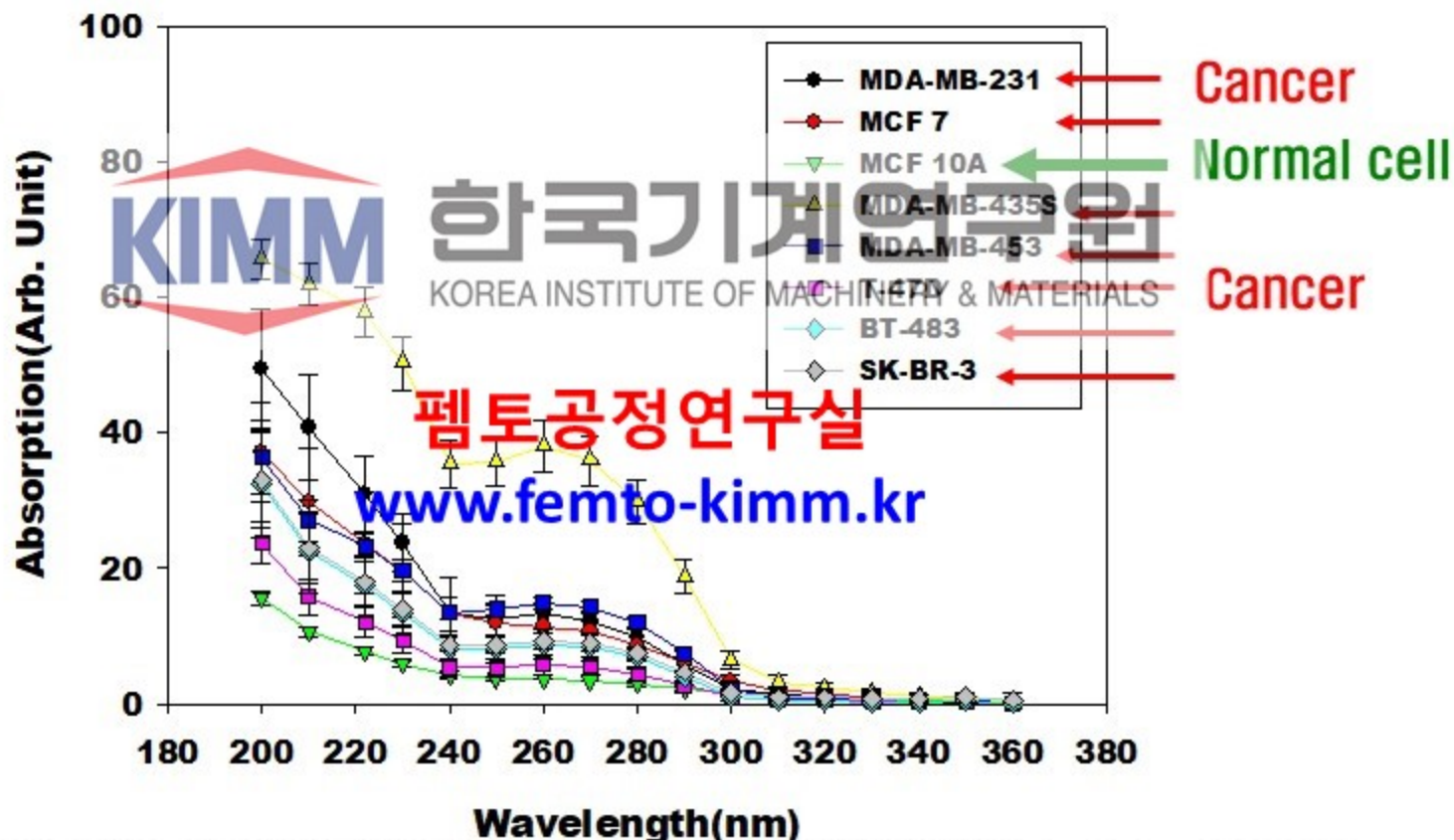
	Cell Name
 Normal cells	한국기계연구원 KOREA INSTITUTE OF MACHINERY & MATERIALS Human mammary epithelial cells, MCF-10A
Weakly invasive	www.femto-kimm.kr MCF-7, T-47D, BT-483
Intermediately invasive	MDA-MB-453, MDA-MB-468, SK-BR-3
Highly invasive	MDA-MB 231, MDA-MB 435S, Hs578T

Breast Cancer Research and Treatment 83:249-289 (2004)

생체세포 선형흡수(UV영역) 특성 연구

● 세포 고유 UV흡수특성 이용 정상세포와 암세포를 100% 진단 가능 [fs 기술]

원천
특허 등록



특허: UV광 흡수스펙트럼을 이용한 세포의 정상세포, 암세포 진단장치 및 방법 [10-2007-0006232]

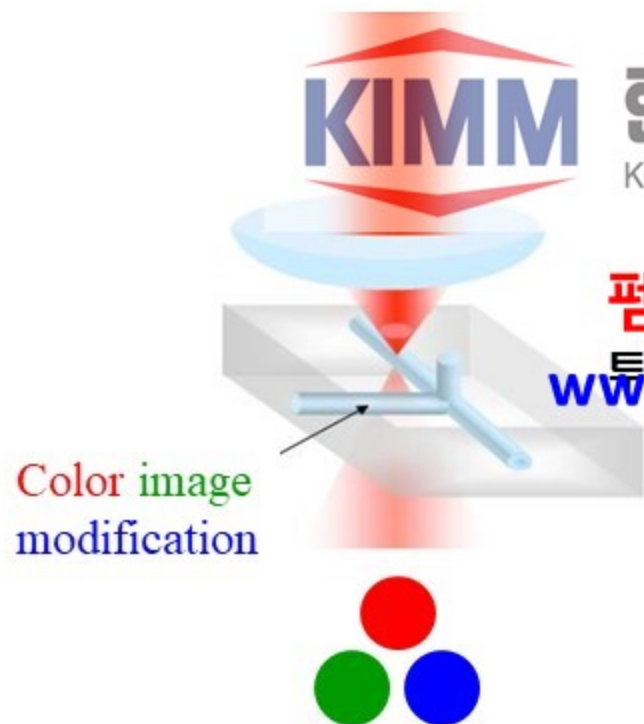
Sung-Hak Cho, Won-Seok Chang, Kwang Ryul Kim, and Jong Wook Hong " Measurement of UV absorption of single living cell for cell manipulation using NIR femtosecond laser" Applied Surface Science 255, 4974-4978 (2009)



펨토공정연구실
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극초단 레이저 직접 묘화에 의한 하이브리드 재료 내부에서의 다양한 기능성 3차원 개질 가공 원천기술 개발

예 : 색상 가공 원천기술 개발



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색상 구현 원천기술 개발

투명유리 내부 색상 구현 기술 연구 (1)

Some examples of color changes

갈색 (yellow color) 구현

배경: 태양광

Laser power	Condition	색변화
:	Length : 8mm 100 μ m 간격 30회	
140 mW		유
110 mW		유
90 mW		유
55 mW		유

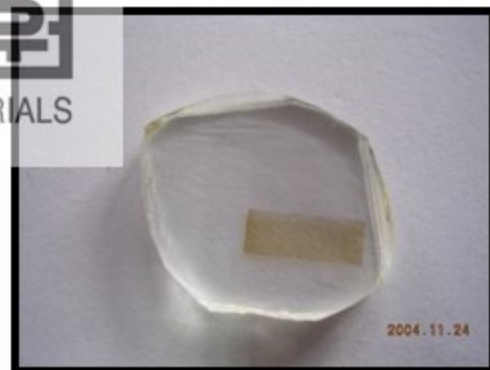


Fig. Image photograph of laser induced glass

Glass material: Ag-doped $45\text{SiO}_2\text{-}24\text{Na}_2\text{O}\text{-}24\text{CaO}\text{-}4\text{P}_2\text{O}_5$

Co-work : 부산대학교 류봉기 교수 (재료공학과)

투명유리 내부 색상 구현 기술 연구 (2)

다양한 투명유리 내부에서 색상 구현 (갈색, 녹색, 노랑) 원천기술 확보
다양한 색상 구현 가능성 확보

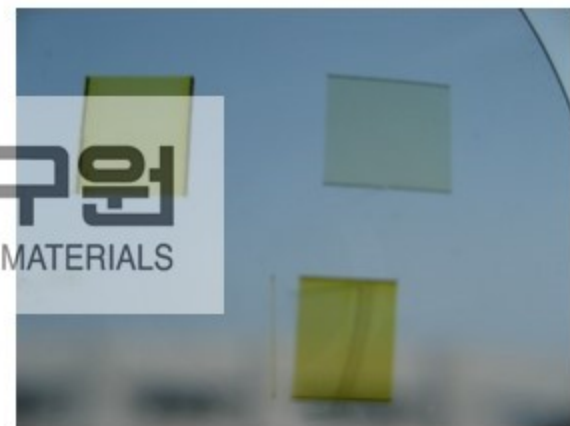


Soda-lime glass

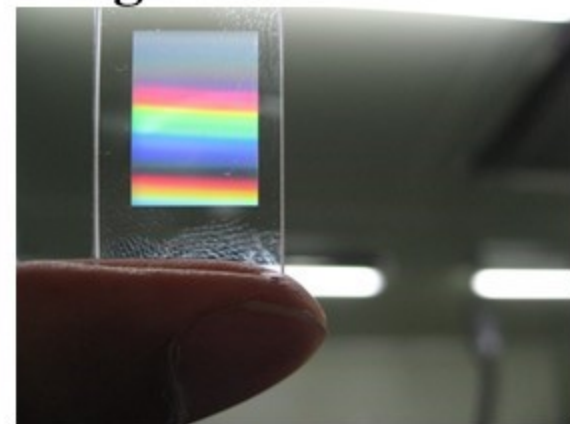


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BK7-glass



펄토초 레이저 응용 반도체 건식 세정 연구

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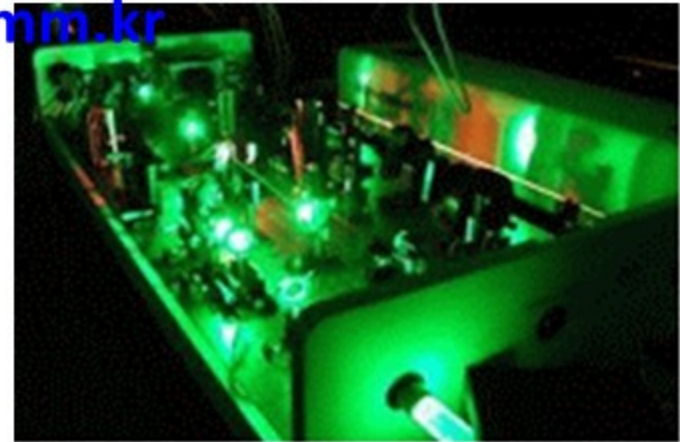
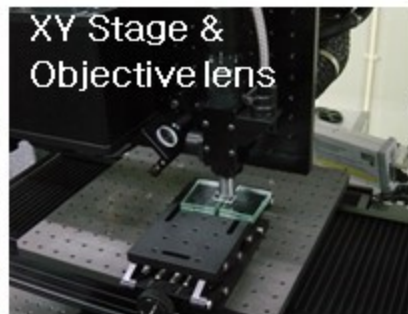
KIMM + [주] 세메스 + [주] IMT

Femtosecond laser in KIMM (1kHz)

- 펨토초 레이저 기반의 세정시스템 시험 환경 구축
(갈바노 스캐너 및 XY 스테이지 이용)

[Specifications]

Laser source	Ti:Sapphire
Wavelength	$\lambda = 790 \text{ nm}$
Pulse energy	3.5 mJ/1 kHz
Pulse duration	100 fs
Beam Diameter	8 mm
Beam Quality(M^2)	≤ 1.8
Beam Mode	TEM ₀₀ Gaussian



Femtosecond laser (KIMM)

펄스 레이저 웨이퍼 건식 세정



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X

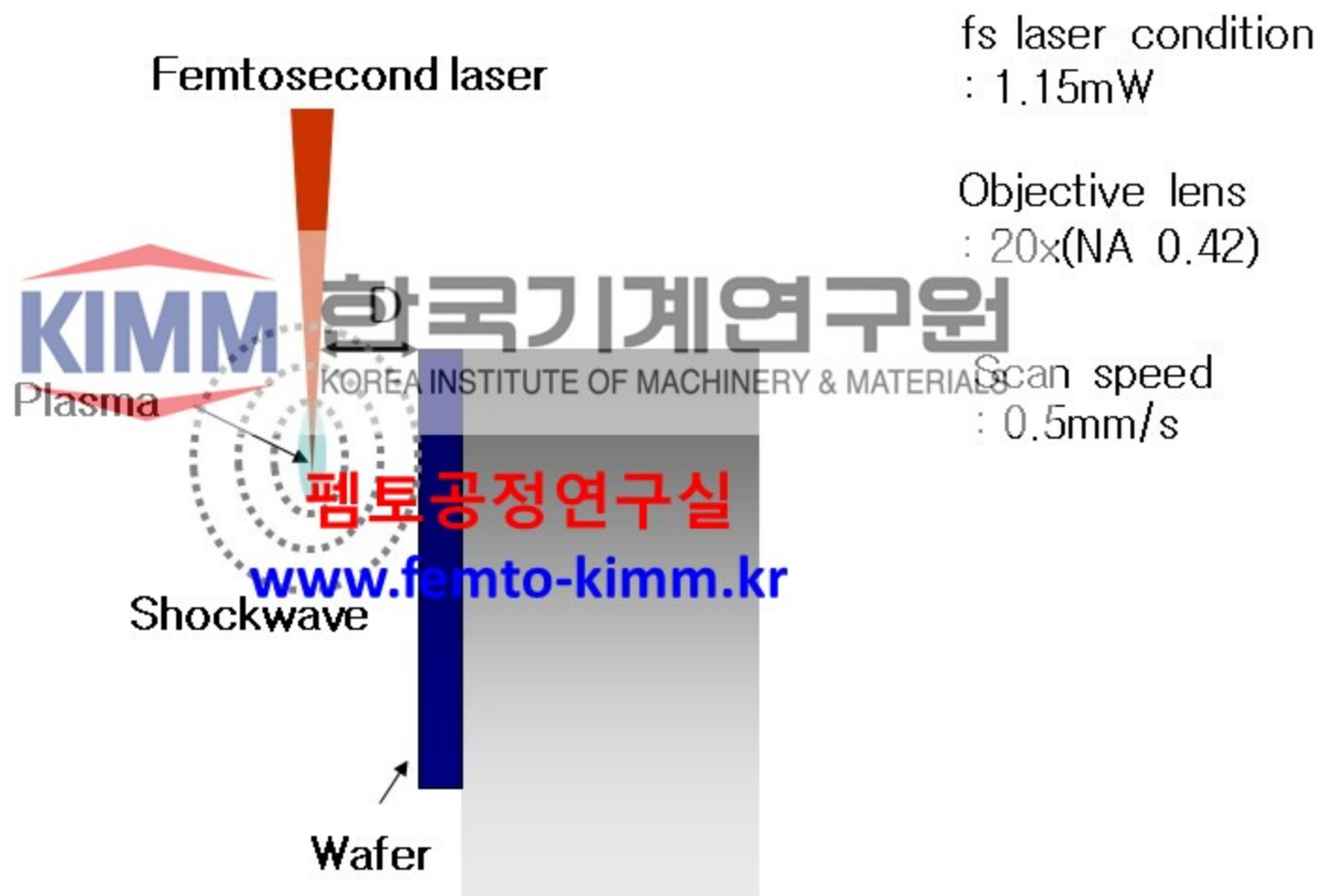
X

O

O

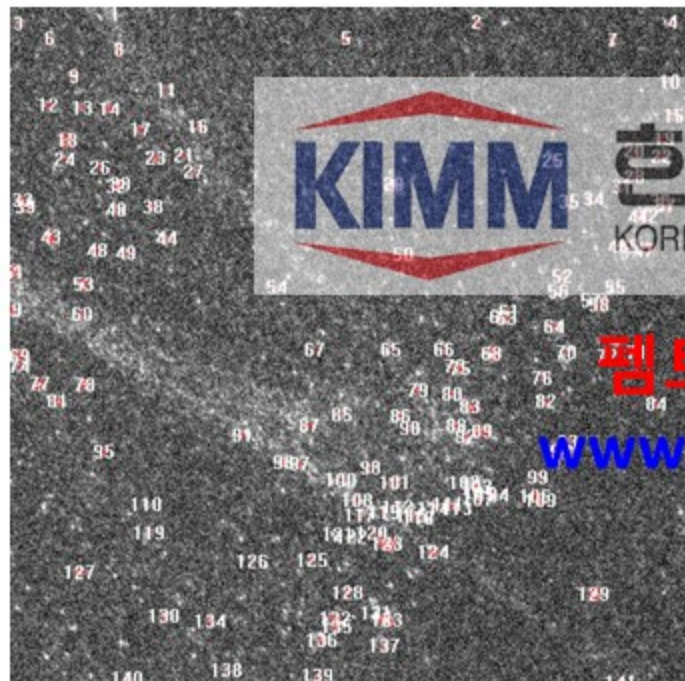
(대면적: 8 인치 이상)

Plasma Shockwave



Plasma Shockwave

Before laser irradiation



141 particles

S-H CHO 국내특허출원 (2008)

After laser irradiation



5 particles (D:150 μm)

약 97% Removed

Plasma self-channeling



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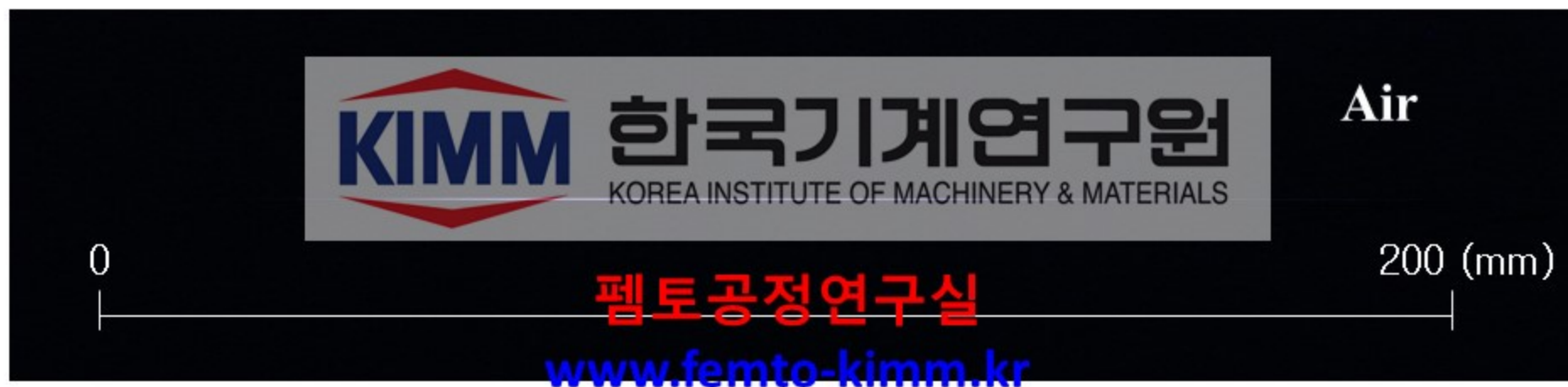
Air

0

200 (mm)

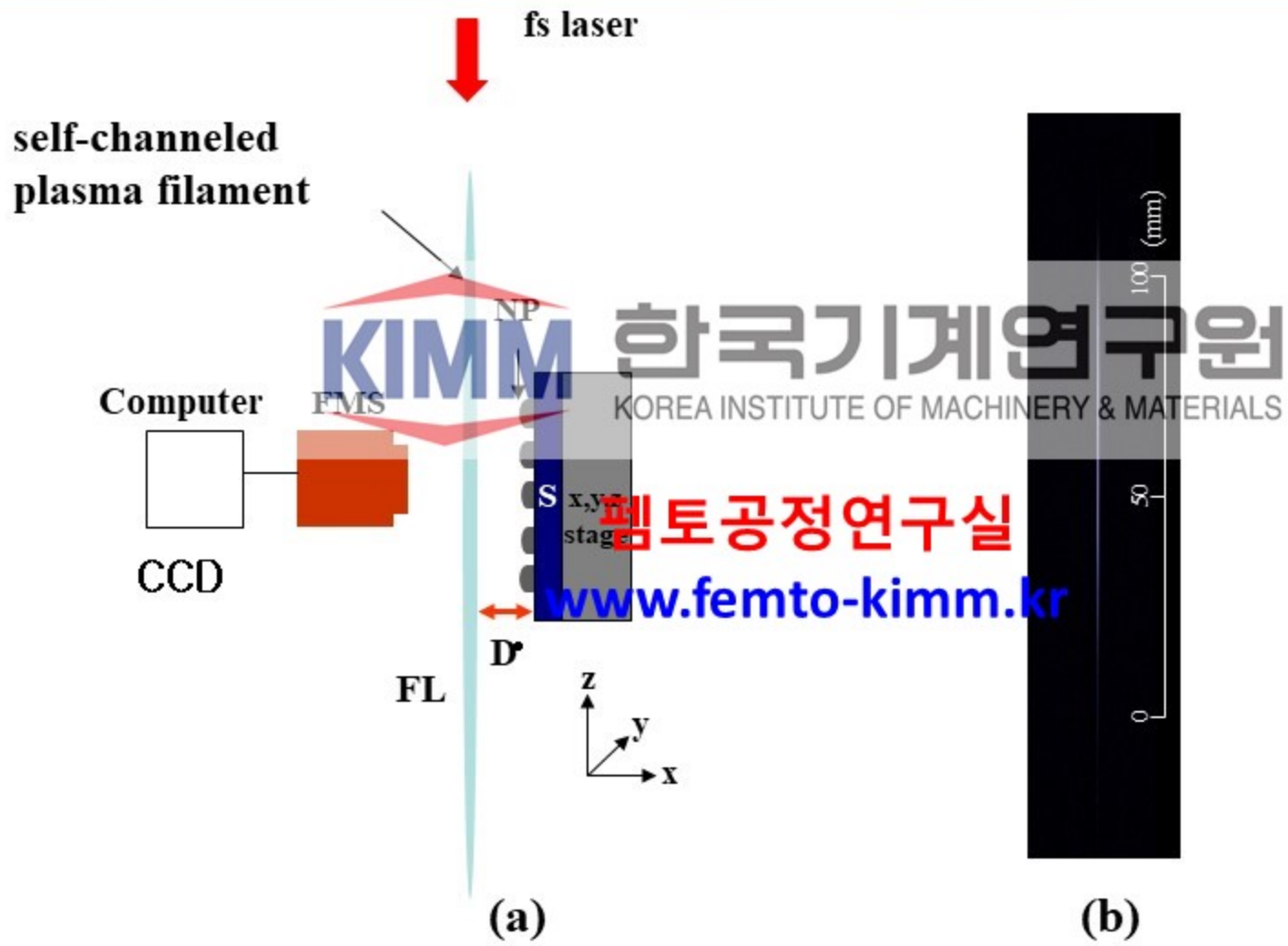
Plasma self-channeling

플라즈마 필라멘트 in Air



Femtosecond laser
peak intensity in plasma
: $> 10^{15}$ W/cm²

Removal of nano particle on silicon wafer using self-channeled plasma filament excited by a femtosecond laser



NP: nano particles, S: silicon wafer, FMS: fluorescent microscope, PF: plasma filament, D: gap distance, S: silica plate (a). Microscopic side view of plasma filament at the input intensity of $5 \times 10^{14} \text{ W/cm}^2$ (b)

Plasma self-channeling

Power : 1.15W

Lens : focal length 30cm

Scan speed: 0.5mm/s, Scan time : 1

Gap distance: 150um

Area size: 20 x 20 (mm)



**약 96% Removed
by 1 time scan (20s)**

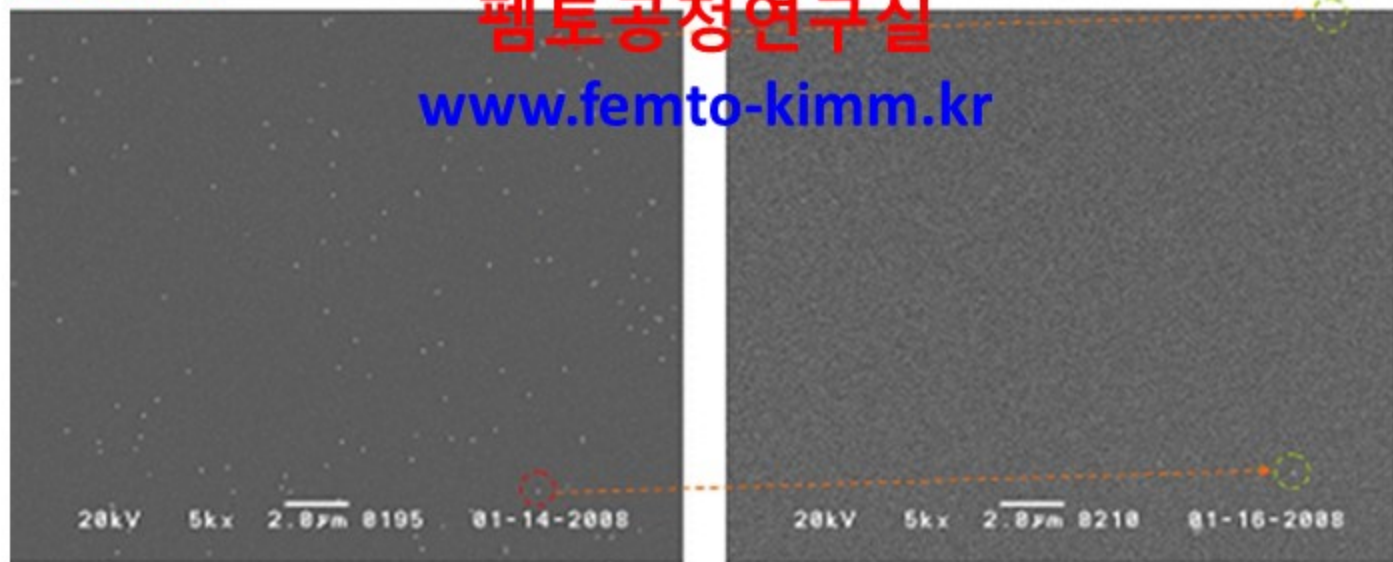


한국기계연구원 플라즈마 처리 기술 개발
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Before laser irradiation **After** laser irradiation

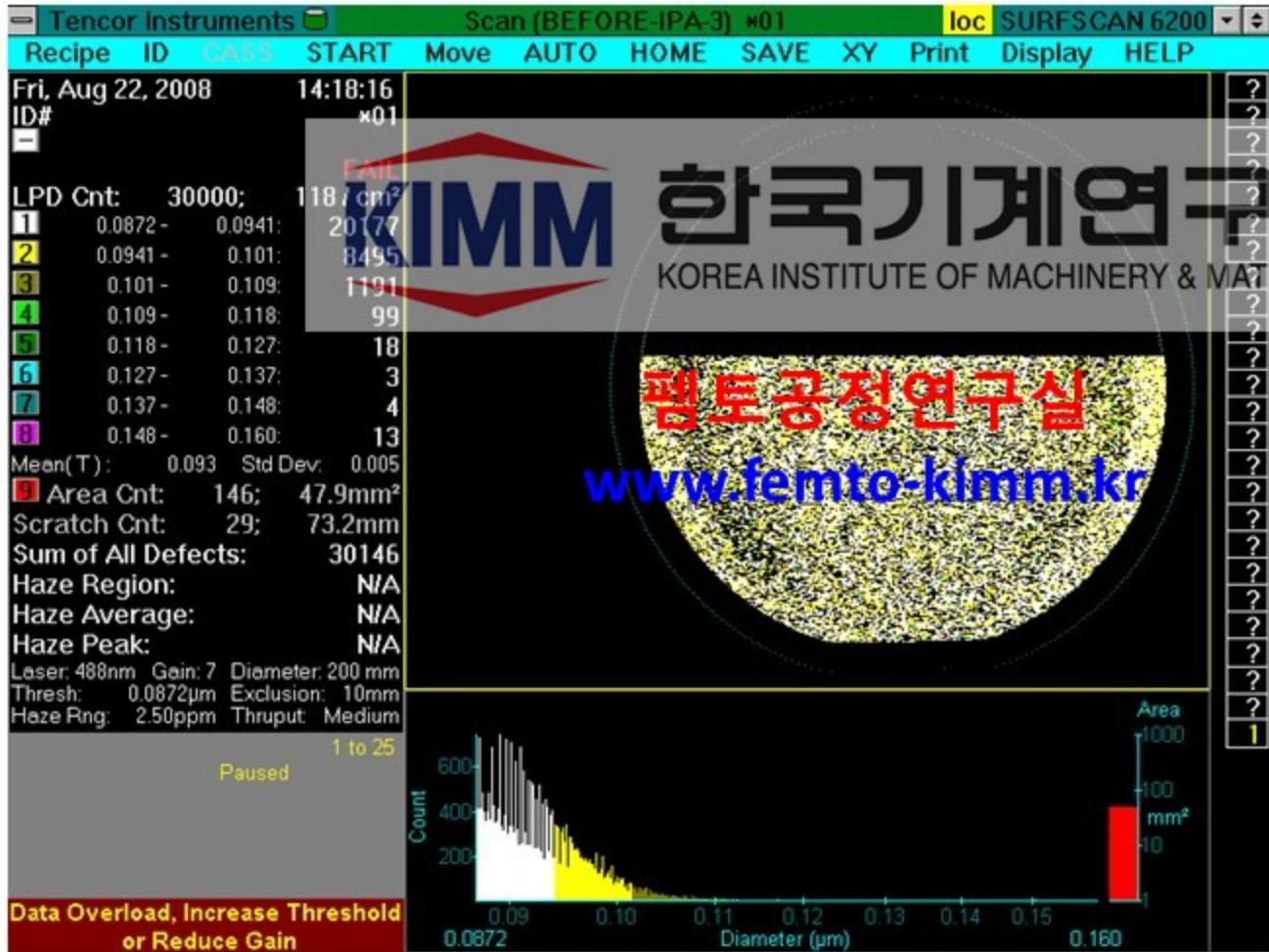
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Laser cleaning using plasma self-filament

New laser dry cleaning method (8 inch wafer, One scan cleaning)



Wafer

70 nm PSL

Now studying

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고에너지빔 초정밀 하이브리드 미세 가공

펨토공정연구실

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펨토초 레이저 + 초음파 진동

KIMM + KAIST + 아주대 + (주)LTS + (주) 휴메드

연구개발 개요

고에너지 빔 응용 초정밀 하이브리드 가공 시스템 개발

Laser precision machining



- 비접촉 가공
- 고속 절단 (10m/min)
- 낮은 정밀도 (0.05mm)
- 열변형/잔류응력 발생
- Burr 발생

Laser ultraprecise hybrid machining

극초단 레이저/초음파진동 하이브리드 가공



- 초미세가공 $\phi < 500\text{nm}$
- 가공분해능 $< 100\text{nm}$
- 열변형/Burr 발생억제
- 난삭제 극미세 가공
- 가공면의 고품위화
- 고세장비(A.R) 출가공

펄스공정연구실

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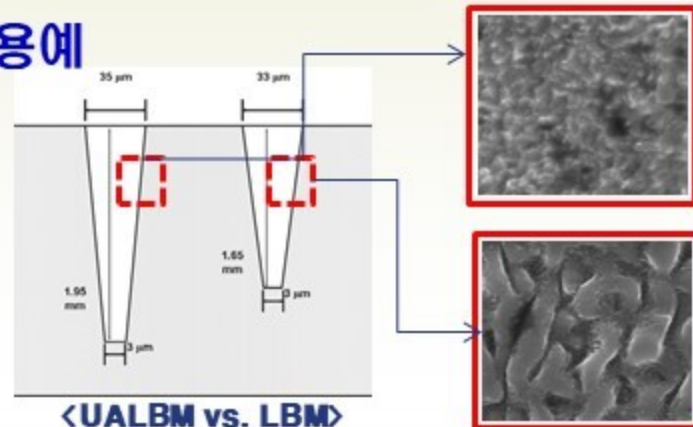
초미세가공, 고품위가공

Ultrasonic assisted machining



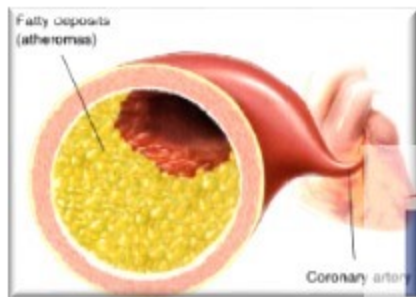
- 고품질 가공면
- 초경질 가공
- 높은 burr 제거 효율
- 낮은 가공효율

적용예

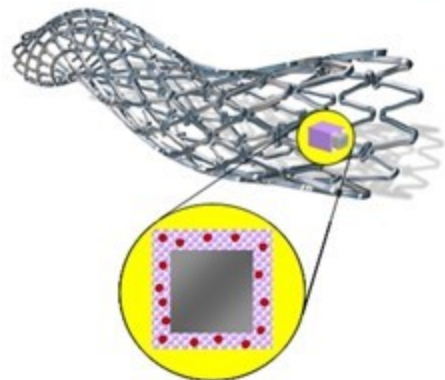
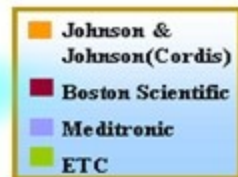
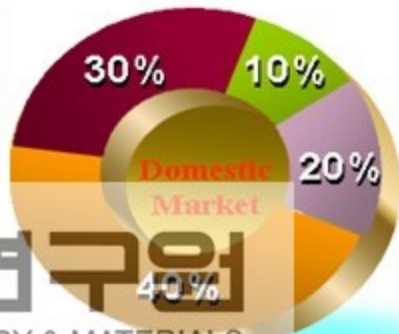


하이브리드 나노가공 적용기술

약물전달 스텐트 (Drug Delivery Stent)



<시장 점유율>



기존의 약물전달 스텐트
[폴리머+약물코팅]



신개념 약물전달 스텐트
[폴리머 미사용]

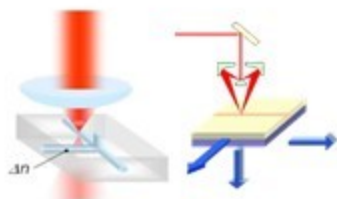


인체잔류 약물함유용 코팅제인 폴리머 미사용 Hot Issue

세계 시장을 외국 4사가 독점적인 위치 선점
국내시장 Stent의 경우 **95% 수입**에 의존
시장 규모: 세계 36조원, 국내 1조원 (2016년)
인구의 고령화로 향후 시장 성장성/안정성 큼

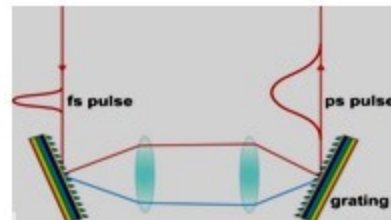
국내업체 활용가능한 미세형상(마이크로,나노) 가공기술부족, 약물전달스텐트 미시도

펨토초 레이저 극미세 가공 관련 기획보 기술 (한국기계연구원)



파장가변기술
SHG, THG
200-1000nm

펄스폭 제어기술
Pulse chirping Tech.
100 fs – 100 ps



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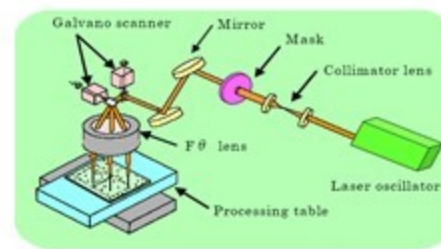
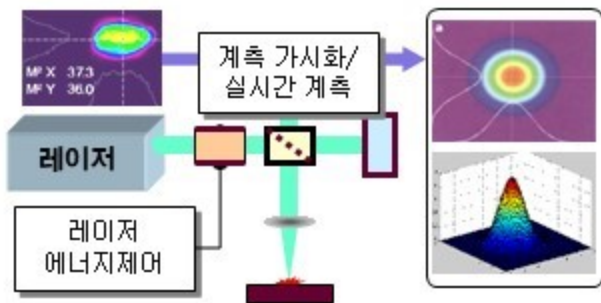
시공간 coupling 기술
Pump-probe Tech.

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시스템 요소기술
광제어 하이브리드 장치
실시간 모니터링 장치
Auto-focus 장치
S/W 개발

**광펄스 에너지/
파워 실시간
제어기술**
In situ beam
control



UV 펨토초 레이저 추가 운영 (2010년 2월부터)

도입장비명: UV 펨토초 레이저 (UV Femtosecond Laser System)

모델명: Solstice (산업용 펨토초 레이저시스템)

제조사: Spectra-Physics (USA)

공급사: Laser Spectronix (KOREA)



주요 사양 [Spec.]

- 레이저 파장: 267nm (DUV), 400nm (UV)
- 펄스 폭: 100 fs (femtosecond, 10^{-15})
- 펄스 에너지: 0.7 mJ/pulse (@5kHz)
- 레이저 파워: 3.5 W
- 레이저 반복율: 1kHz, 5kHz, 10kHz
- 빔 모드: TEM₀₀
- 빔 직경: 10.0mm

주요 가공 특성

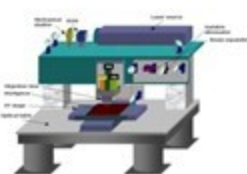
- 재료무의존성 가공, 비열적가공
- 가공 홀폭: 1-50um, (최대: >500nm)
- 가공분해능: 최대 50nm
- 세장비: 최대 5 이상 (@10um 직경)
- 최대 출력 파워: $>10^{15}$ W/cm²

세계최고수준의 고출력 UV 펨토초 레이저

재료무의존성, 고세장비 초미세가공 가능

적용 가능 분야

PCB, FPCB 공정
[삼성전기]
50조원



기준년도: 2016년
시장규모: 세계시장



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1차 시장
2차 시장

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1차 시장: 펄초 레이저 기반 초정밀 극미세 가공 시스템
2차 시장: 펄초 광학 연구실

바이오칩
Micro-electronic device
Semi-conductor
자동차 부품
대형 디스플레이 장비
대형 LCD repair 공정 [삼성전자] 80조원

펄초 레이저 기반
초정밀 극미세
가공 시스템
(가공기 시장)
의료부품
약물 전달 스텐트 [휴메드] 36조원

Nano patterning
초정밀 부품(금형)
광부품, 제어 기술
바이오기기
데이터 저장 부품
핸드폰 부품
디지털 X-형광판 [뷰익스] 8조원

국가 주력 생산 제품의 기반 제조 기술

Conclusion

- ❖ 연구배경 - 수요 현황, 시장 규모
- ❖ 극초단펨토초 레이저란?
- ❖ 펨토초 레이저 가공 장점
- ❖ 펨토초 레이저 기반 가공 시스템 제품화/상용화 연구
KIMM KOREA INSTITUTE OF MACHINERY & MATERIALS
- ❖ Research Topics with femtosecond laser in KIMM
 - Internal Material Processing
 - Surface Material Processing
 - 펨토초 레이저 응용 공작기계의 초미세 가공 및 전자기기 개발
 - 투명유리 내부 색상 구현 기술 연구
 - 펨토초 레이저 응용 반도체 건식 세정 연구
 - 현재 진행중인 국책과제 소개
- ❖ 펨토초 레이저 미세가공 활용 지원지원 사례

➡ 펨토초 레이저 극미세가공 분야 시장 열림/상용화

Announcement (I)

<http://apls2010.org/>

☆ ☆ :::: apls2010 ::::

contact:apls2010@kaist.ac.kr Admin

APLS 2010

The 7th Asia-Pacific Laser Symposium
May 11-15, 2010, Jeju island, Korea

HOME

PROGRAM

REGISTRATION

SUBMISSION

TRAVEL

COMMITTEE

LINKS



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Topics

High Power Lasers
Ultrashort Intense Lasers
Laser Material Processing
Laser Applications In Medical Science and Biology
Laser Spectroscopy and Nonlinear Optics
Terahertz Generation and Application
Femtochemistry

Important Dates

Summary submission: January 4 – March 1, 2010
Registration: January 4 – March 28, 2010
Late Registration: After March 28, 2010

Organized by Optical Society of Korea
and Local Organization Committee of APLS 2010
Chair: Jongmin Lee (GIST, Korea)

완료



인터넷

100%

시작



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LPM 2010

11th International Symposium on
Laser Precision Microfabrication
June 7 to 10, 2010

Messe Stuttgart
Key to markets



LPM » About LPM » Aim and Scope

페토공정연구실

■ Welcome to join us at www.femto-kimm.kr Contact

Miniaturization and high precision are rapidly becoming a requirement in many industrial processes and products. As a result, there is greater interest in the use of laser micro fabrication approaches to achieve these goals. The International Symposium on Laser Precision Microfabrication (LPM) is annually held to provide a forum for research and technology development in the area of laser micro/ nano fabrication. The unique aspect of this symposium is the interchange between fundamental research and industrial applications.

LPM is held alternatively in Japan and in other host countries. To date, LPM has been successfully hosted in Omiya, Singapore, Osaka, Munich, Nara, Williamsburg, Kyoto, Vienna, Quebec and Kobe.

In 2010 it will be held in the International Congress Center (ICS) on the Stuttgart trade fairgrounds, concurrently with the international trade fair for system solutions in laser material processing, Lasys, and the Stuttgart Laser Technology Forum (SLT).

Stuttgart, well known as car capital is also the center of one of the most advanced regions in the field of manufacturing with lasers. Suppliers like Trumpf and pioneering users like Daimler and Bosch are located here and

Programme Chair
Prof. Dr. Friedrich Dausinger
Co-Chair LPM 2010
[E-Mail](#)

Organisers



JLPS
Japan Laser Processing Society
LPM 2010 Office
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Landesmesse Stuttgart GmbH
Messepiazza 1
70629 Stuttgart
Phone +49 711 18560-0

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- Aim and Scope
- LPM Topics
- Committees
- Call for papers
- Programme
- Registration
- Lasys 2010
- Travel and accommodation
- Overview exhibition halls
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- Partners and links

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KIMM's Global Network Femtosecond Laser Material Processing



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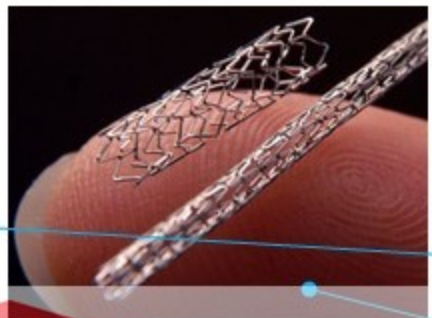
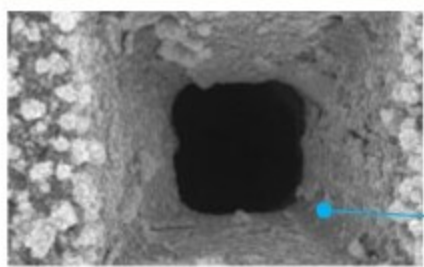
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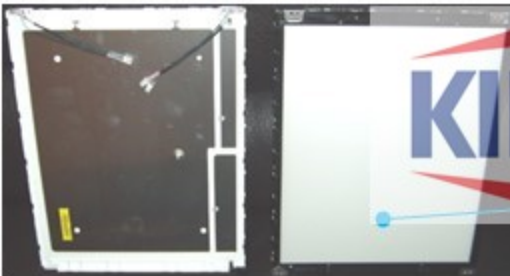


기업 애로 기술 문의 환영 - 레이저 미세가공 / 공정분야



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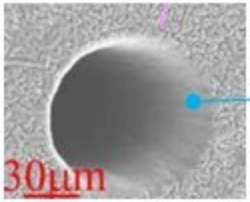
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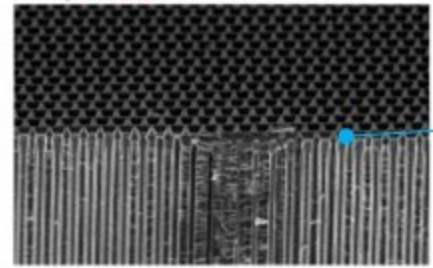
펄스 레이저 가공 공작기계 부품

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금형부품

연료전지



문의: 조 성학 E.mail: shcho@kimm.re.kr Tel.: 042-868-7077

Thank you !!

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