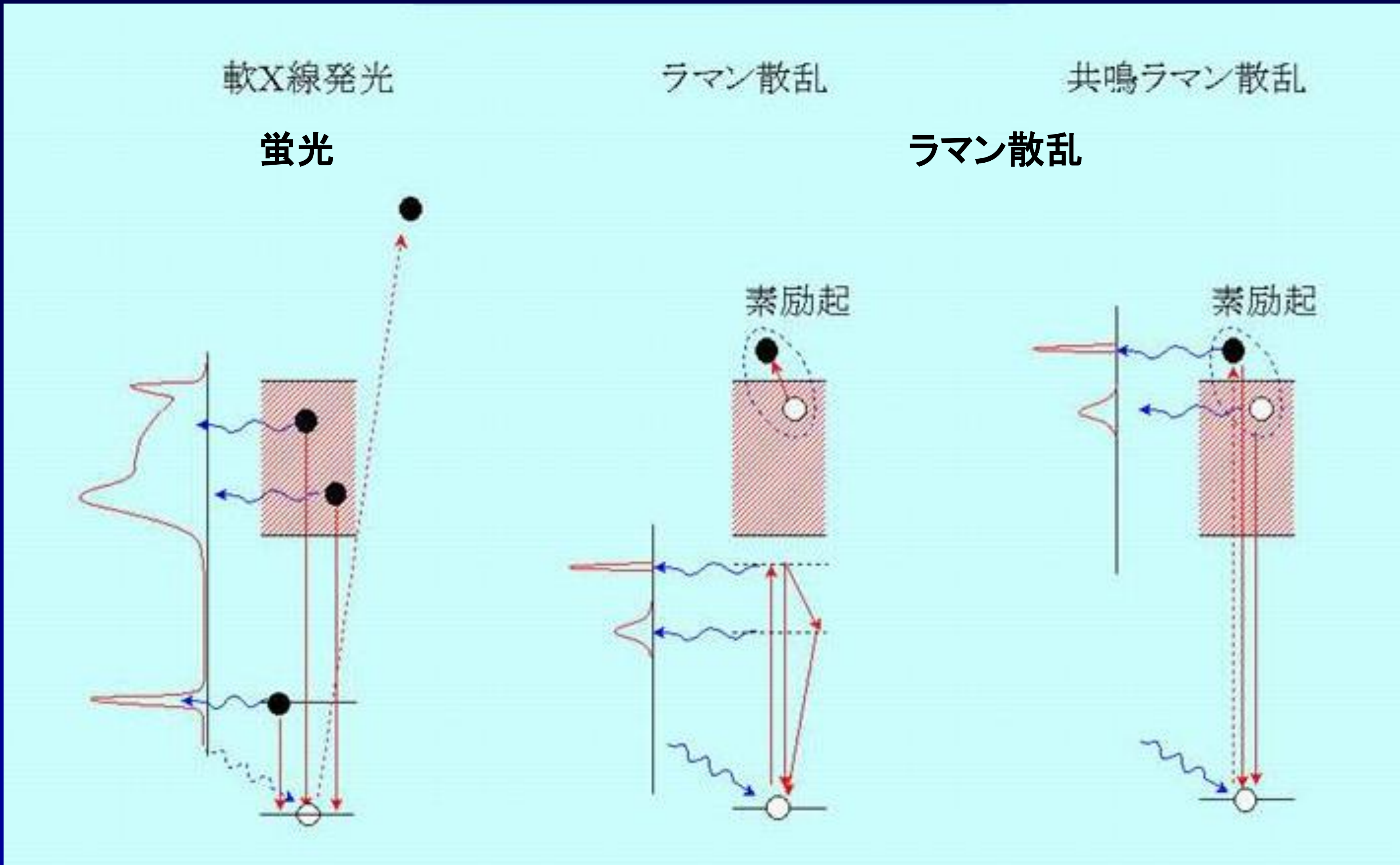
PF BL2Cにおける発光実験の現状と展望
The present condition and the future view of a x-ray emission experiment at BL2C in Photon Factory.

弘前大学
手塚　泰久

共同研究者
中島伸夫、佐藤仁、**森本理**（広島大）
石渡洋一（佐賀大）
大沢仁志（JASRI/SPring-8）、野沢俊介（KEK-PF）、
岩住俊明（大阪府大）

Energy Diagram of SXES and SXRS

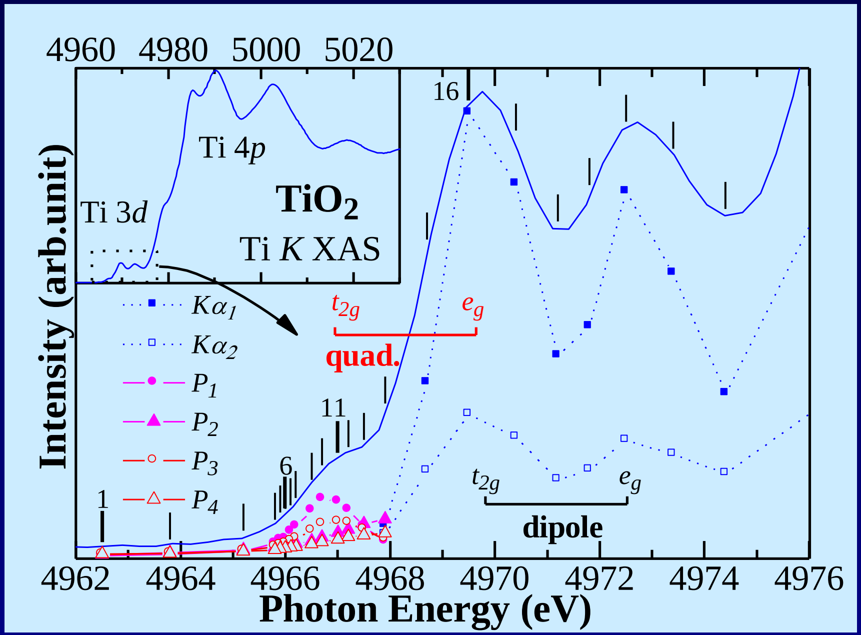


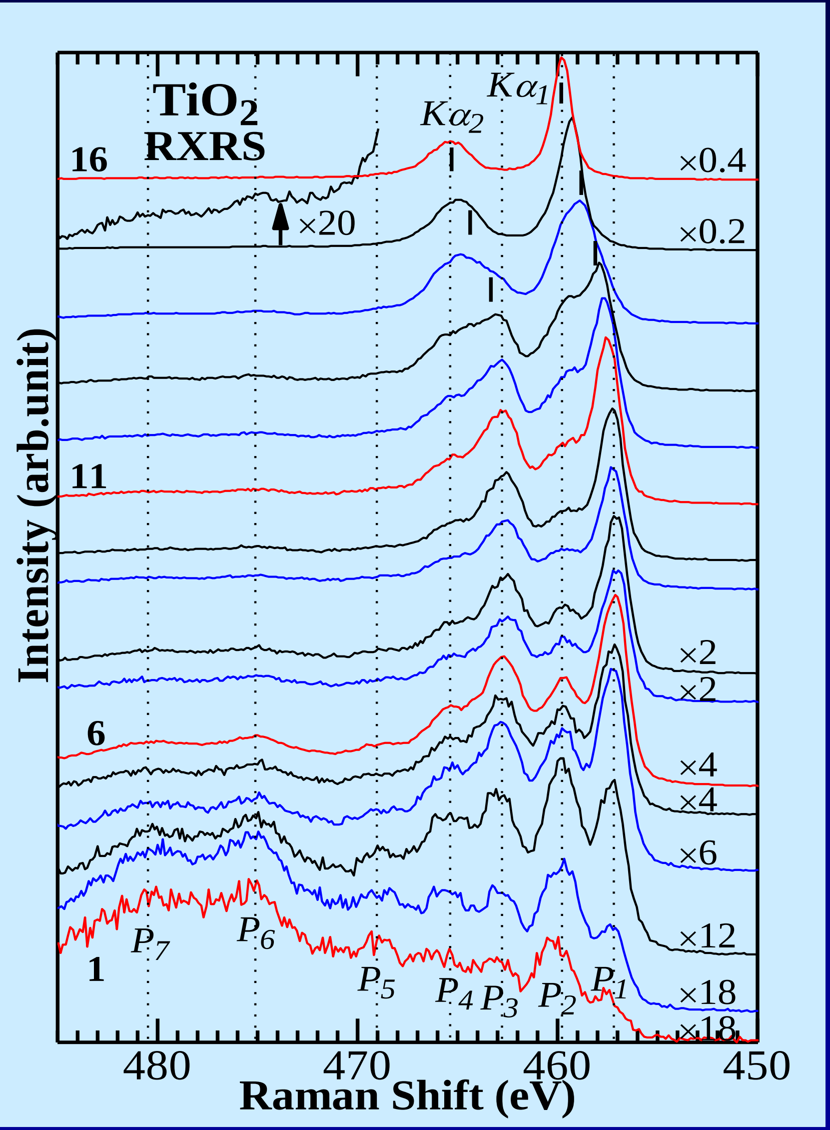
部分状態密度

素励起（エキシトン・フォノン etc）

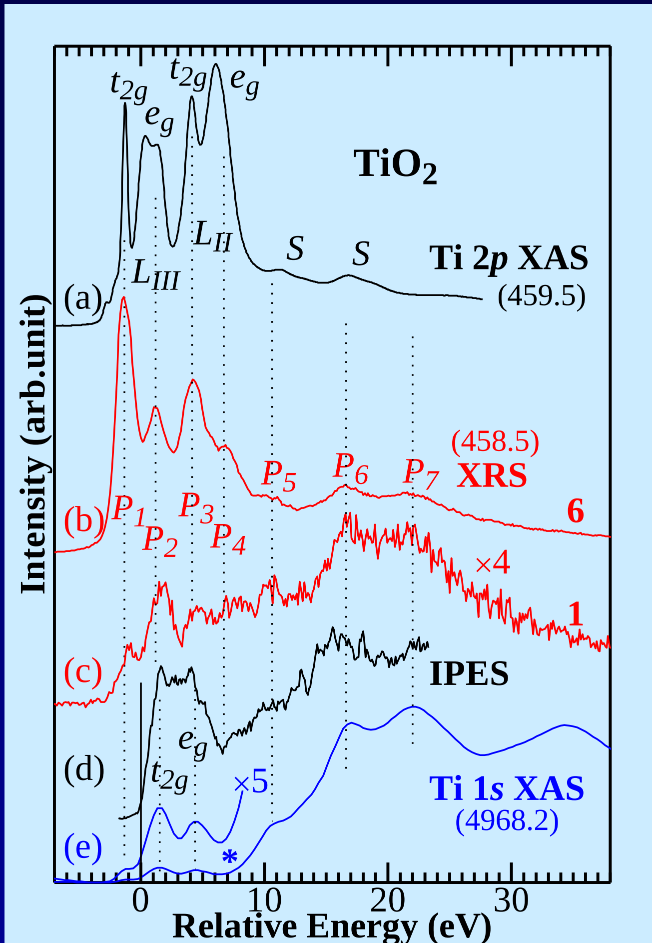
Raman Spectra of TiO_2

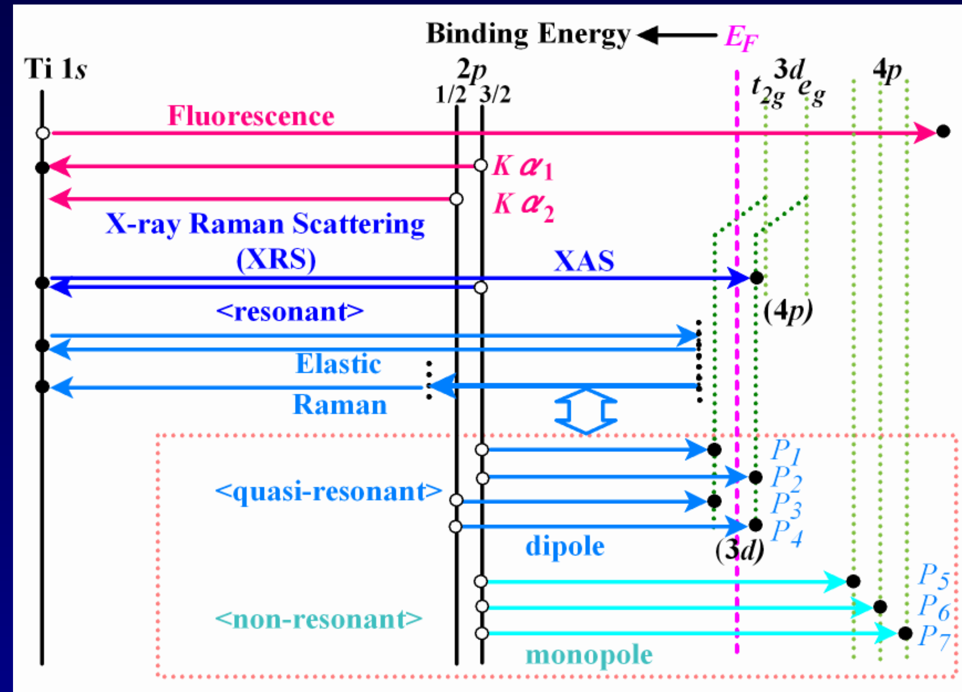
Ti *K* resonance





Comparison of Spectra





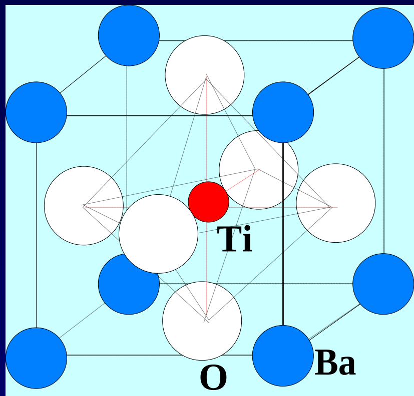
Raman Tensor

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} a & d & e \\ d & b & f \\ e & f & c \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

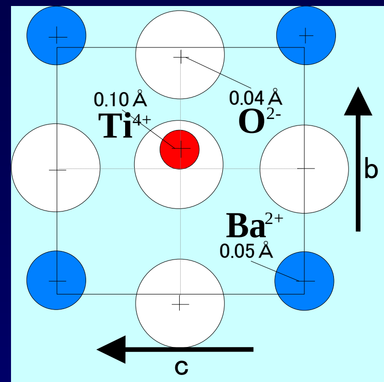
Selection Rule (non-resonant)

g-mode	u-mode
monopole (Raman)	dipole (absorption)

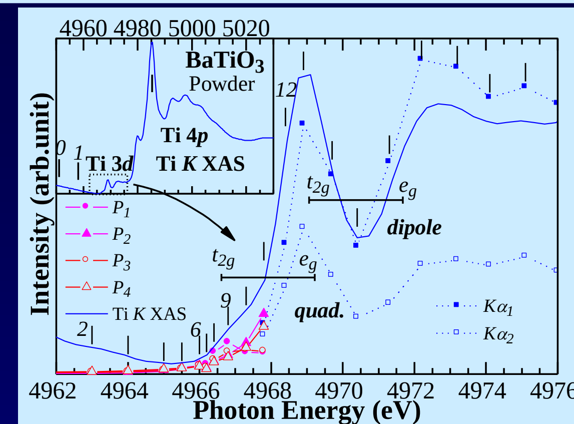
Raman Spectra of $BaTiO_3$



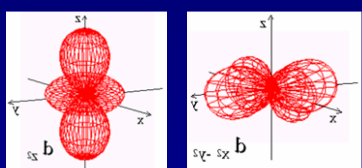
Perovskite Structure



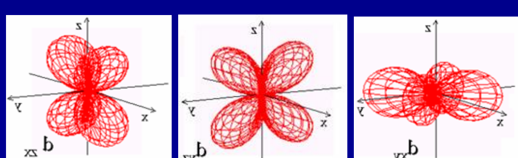
displacement of ions
(tetragonal phase)

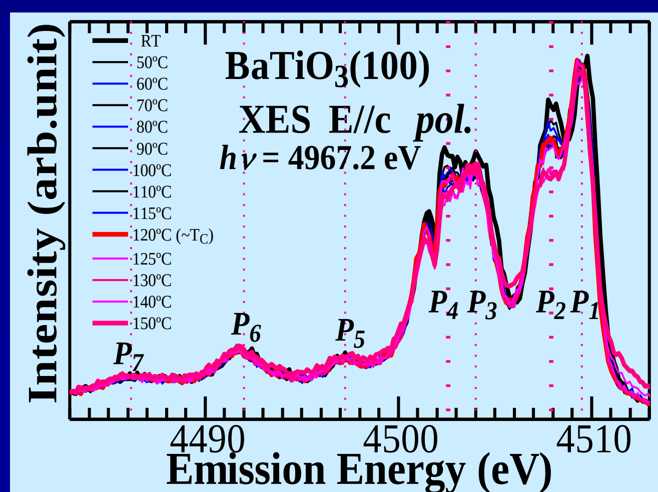


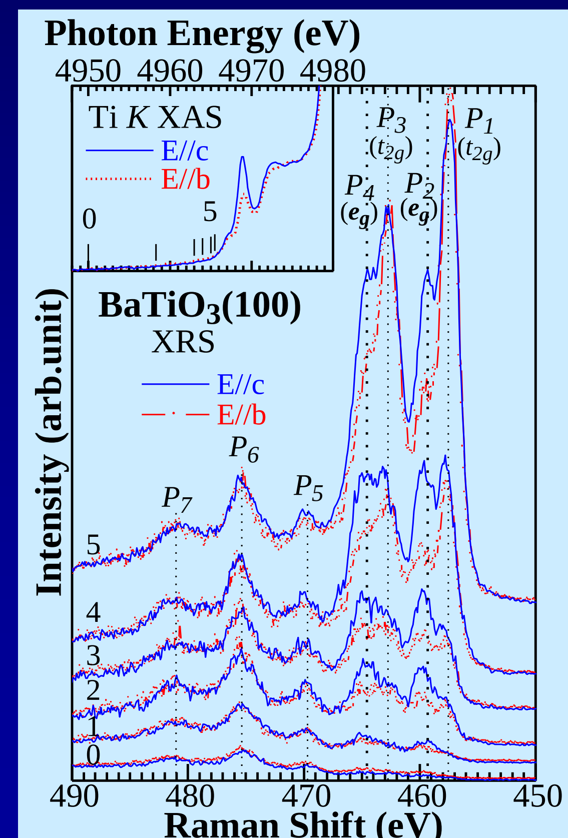
e_g-orbital



t_{2g}-orbital



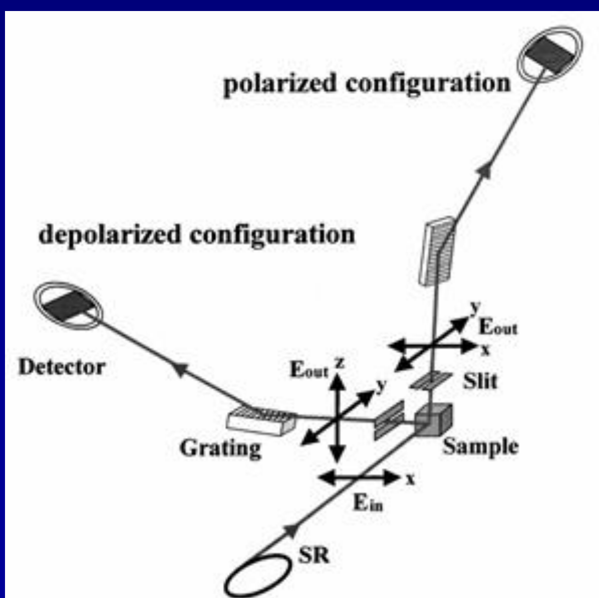


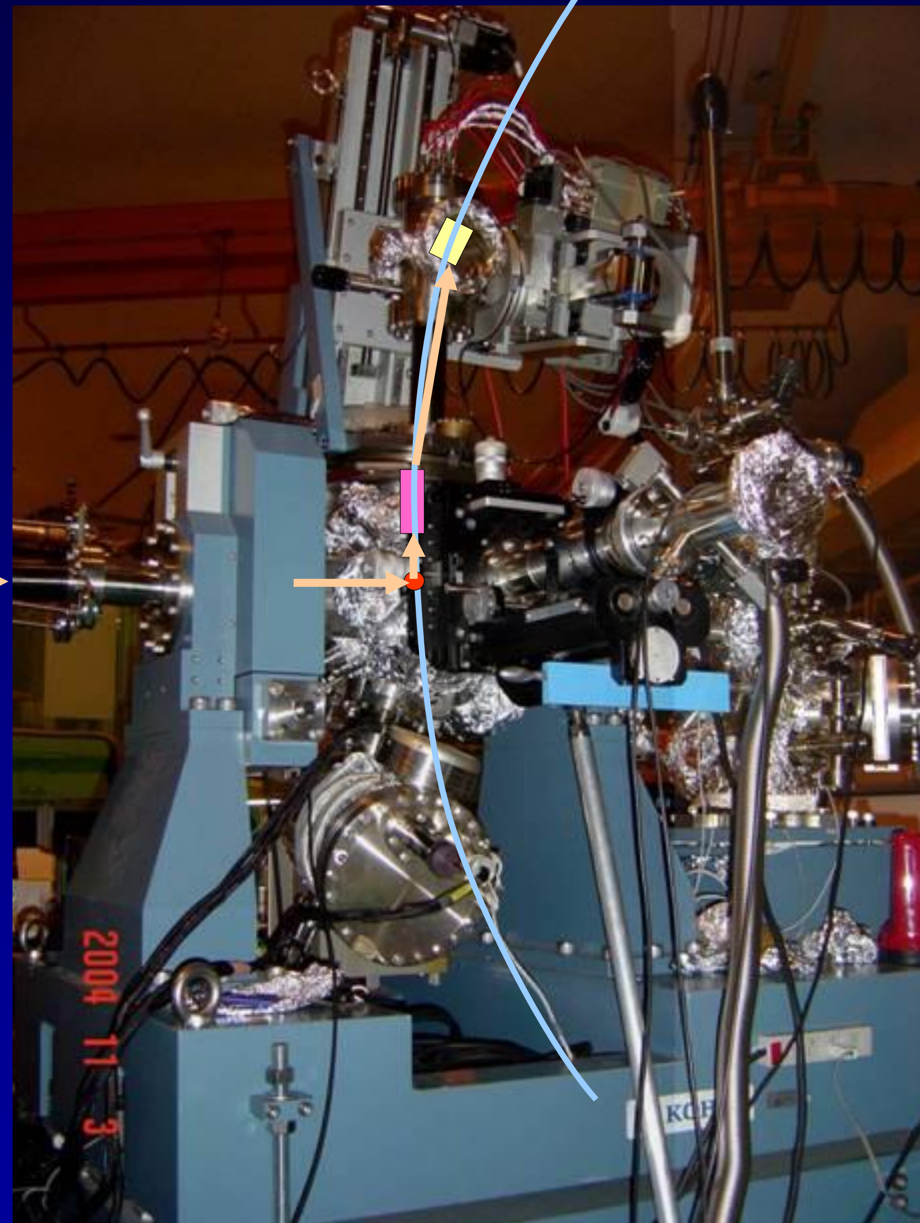


SXES Spectrometer

SXES Spectrometer

@PF_BL2c





Polarized Configuration

軟X線発光@PFBL2C

経緯

1991年～軟X線発光分光器の建設（BL-19B／物性研）
1994年～BL-19B共同利用開始

1996年～可変偏光分光器の建設
S課題（辛G＠物性研）で建設（BL-2C）

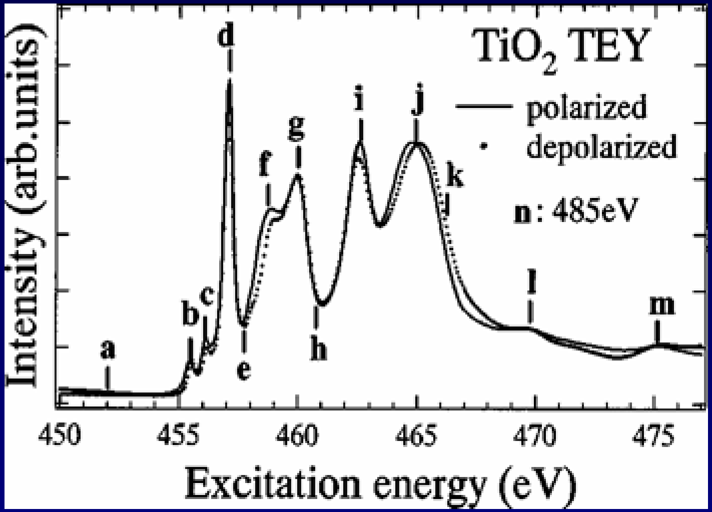
2003年　物性研グループの撤退
暫定的に手塚が引き受ける

2004年　軟X線発光ユーザーグループの立ち上げ

2010年　ユーザーグループ運営ステーション化
2011年度末まで

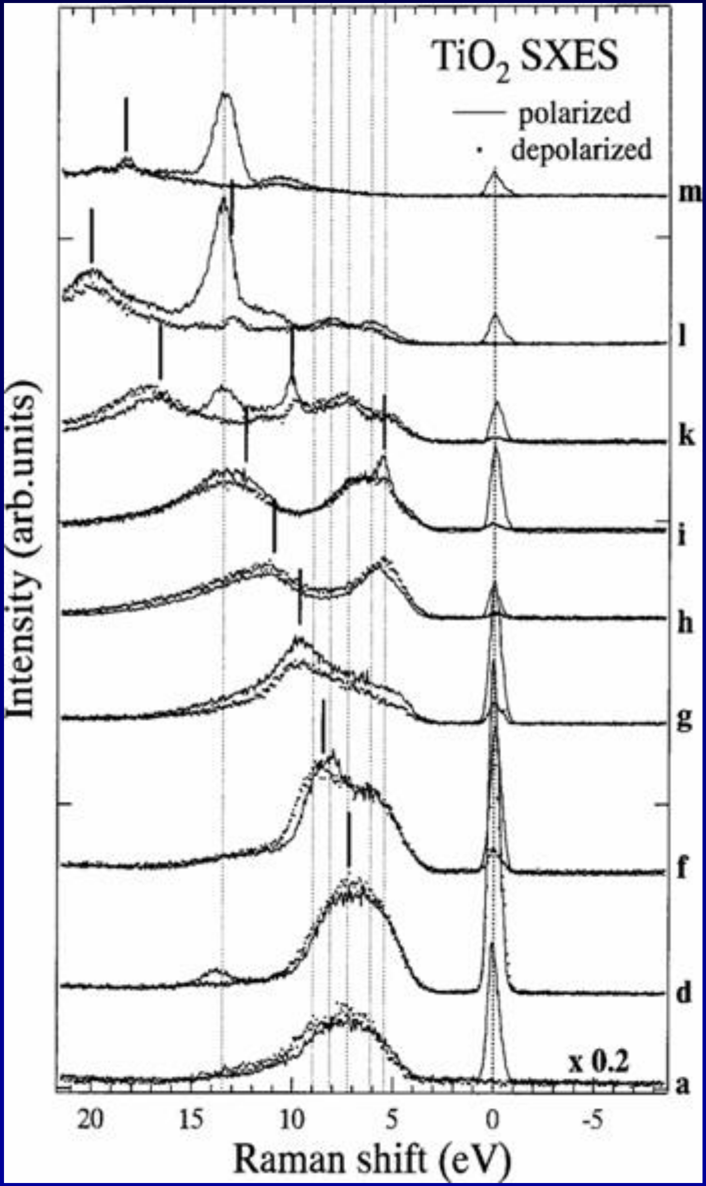
Raman Scattering of TiO_2

CT excitations



Harada et al., Phys. Rev. B 61, 12854 (2000)

Ti^{4+} (d^0)



改造1:計測系の更新

Thanks!　Dr. Morimoto

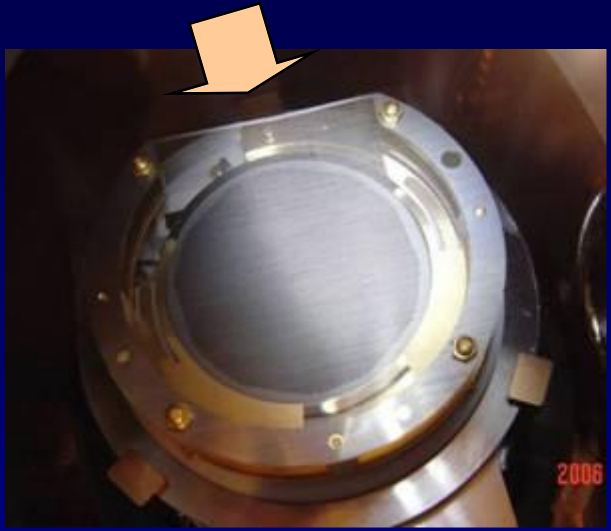
コンピュータ&IFの更新

⇨ Dead Timeの削減、効率3割り増し

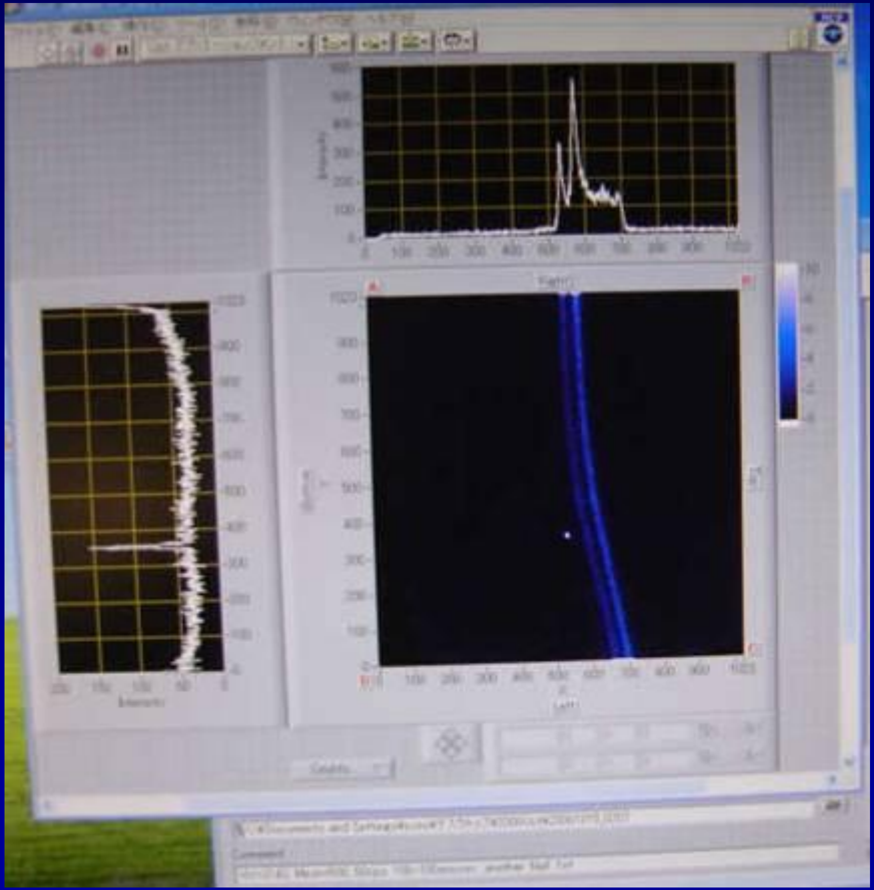
測定プログラムの更新（2D測定）

⇨ 積分パラメータの可視化

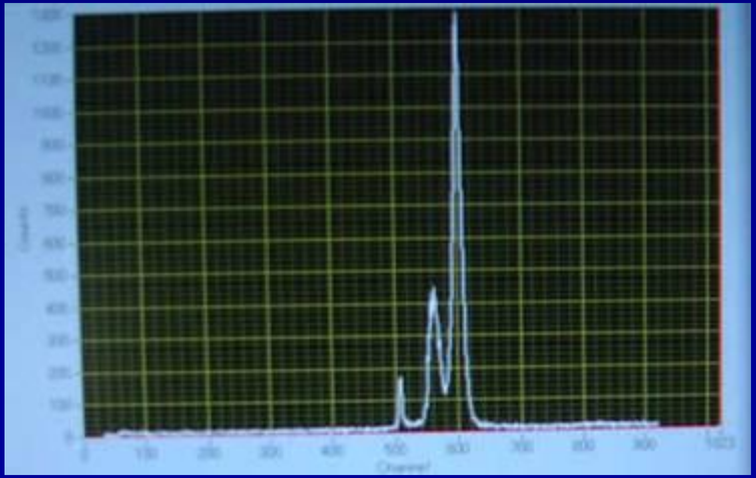
Hot Spotの除去



2D Detector (Quanter Tech.)

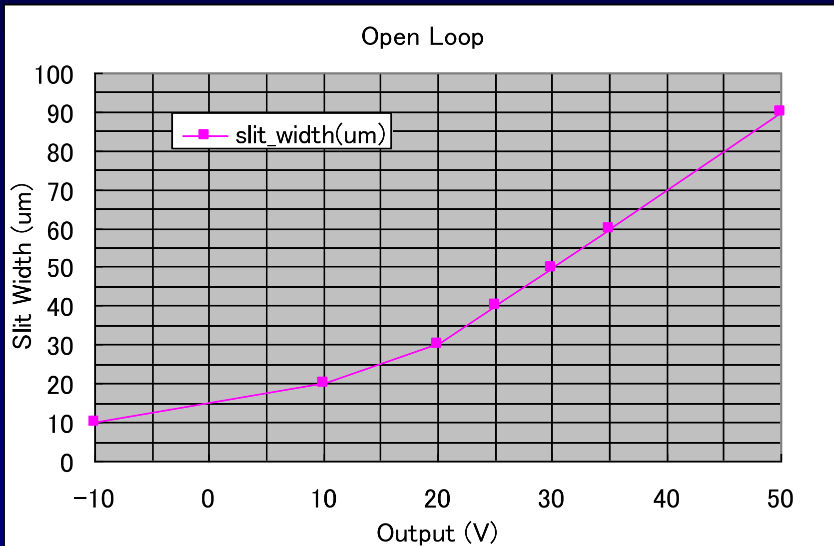


2D Spectrum

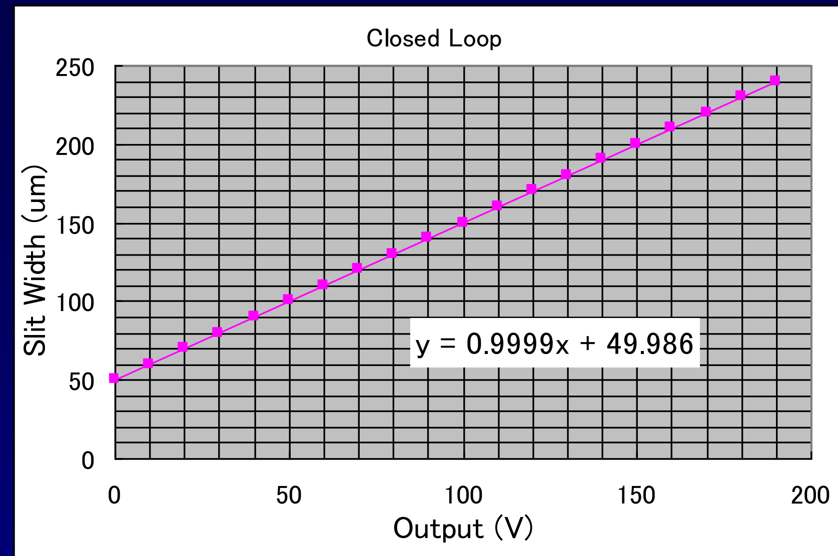


1D Spectrum

改造2:スリットの可変化(ピエゾスリット)



フィードバック無し



フィードバック有り

改造前はスリットがつぶれていた(<5μm)為、単純比較は不可能だが

強度10〜100倍

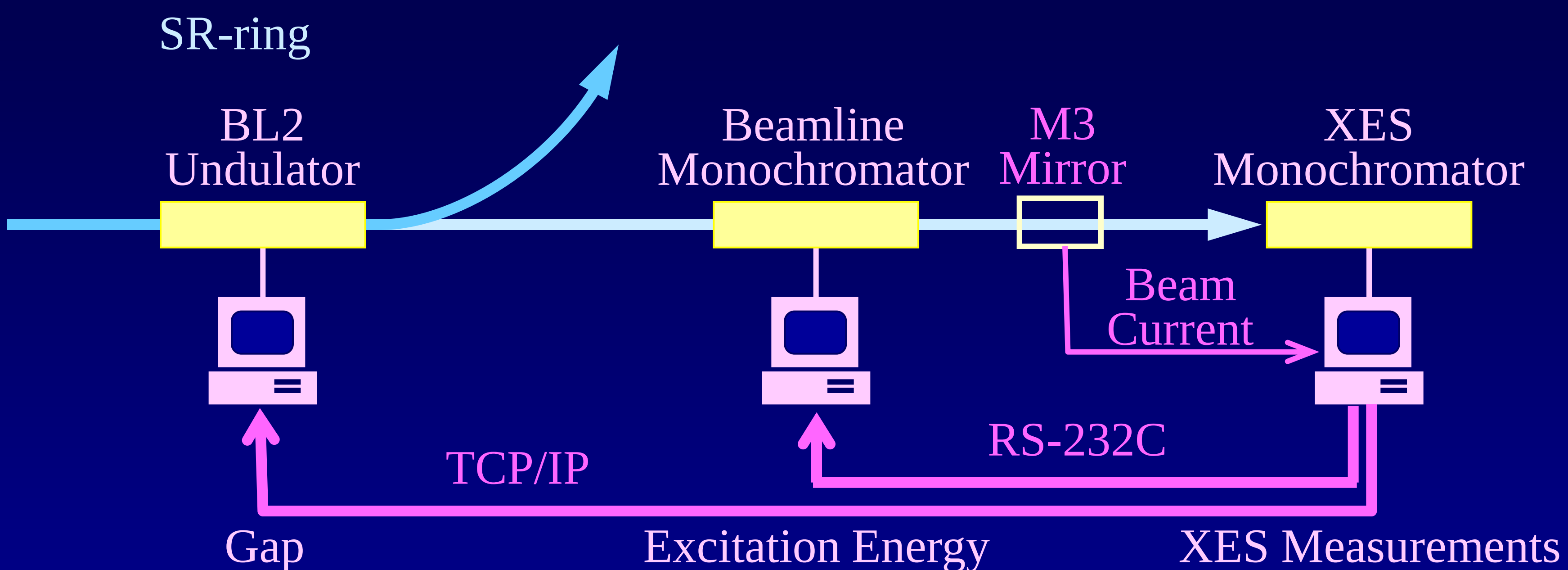
Full Openで部分蛍光収量の測定が可能に。

Partial Fluorescence Yield (PFY)

Partial Photon Yield (PPY)

改造3:ビームラインの遠隔操作

Thanks!　Dr. Morimoto



- 発光測定の自動化
- ビーム強度の取り込み
- SRリングのTop-up運転（BL-close無し、強度変化無し）

共鳴スペクトルの測定無限!?

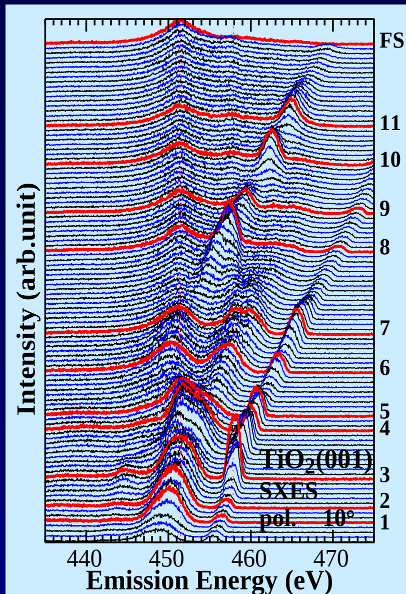
3D表示（等高線表示）

SXRS of TiO_2 (rutile)

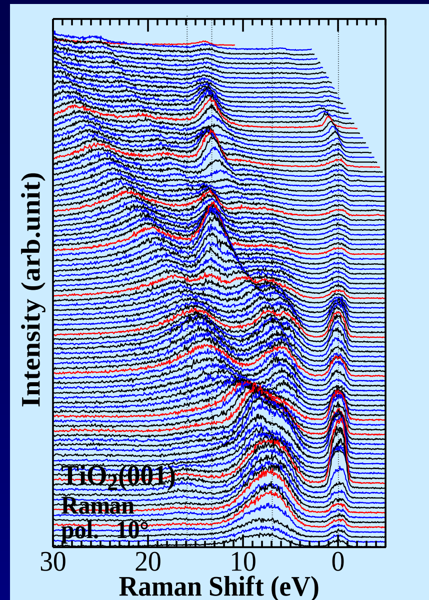
ΔE ~ 1.5eV
18 hours

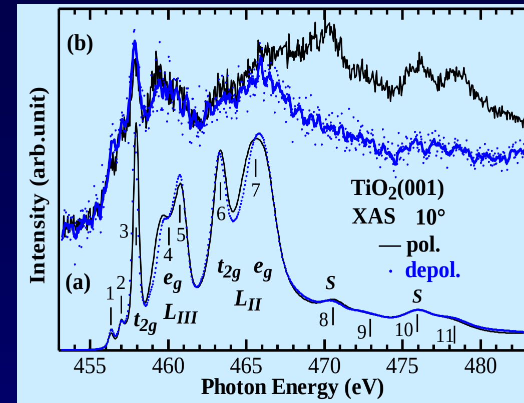
polarized

XES



Raman

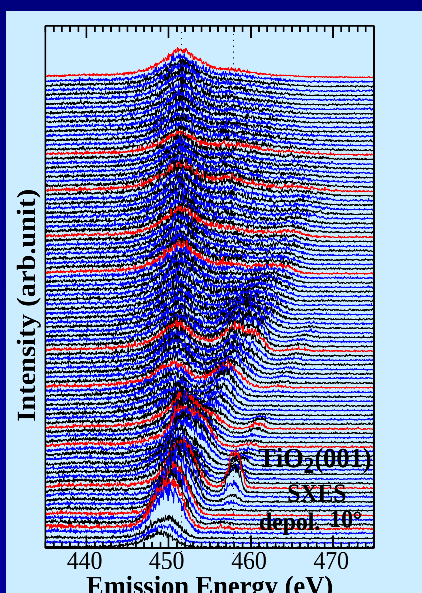


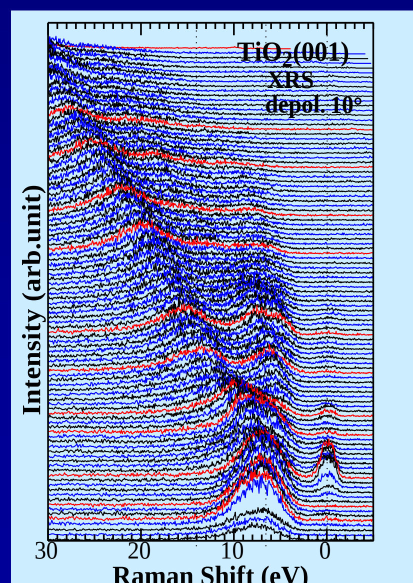


(b) PPY (Partial Photon Yield)

(a) TEY (Total Electron Yield)

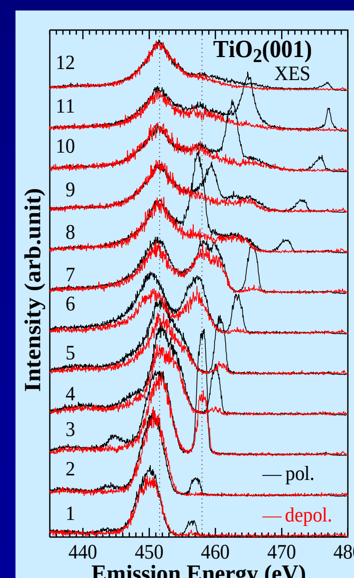
depolarized



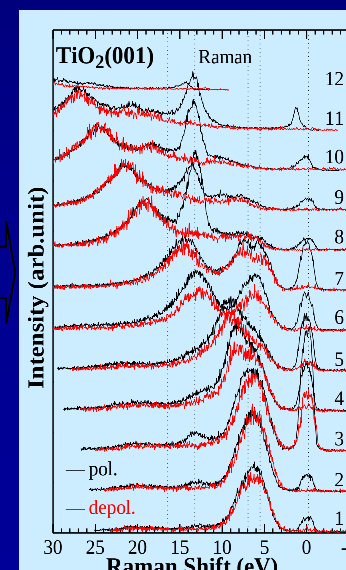


polarization dependence

XES



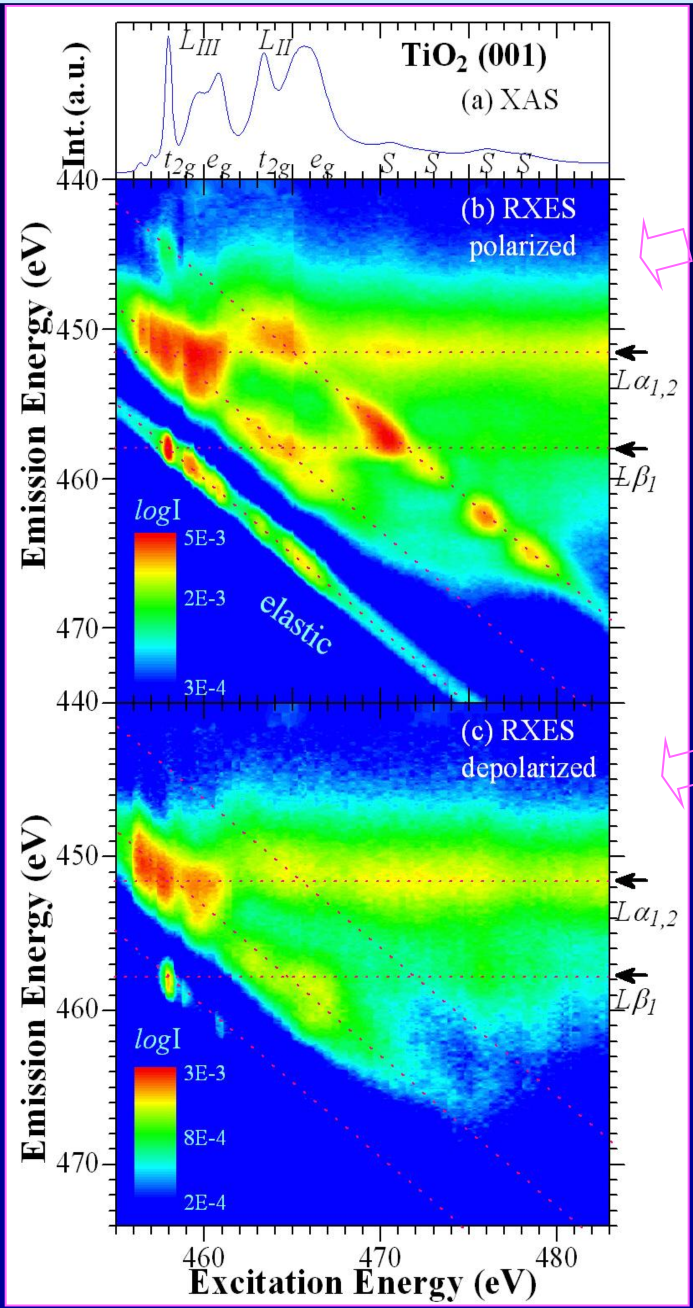
Raman

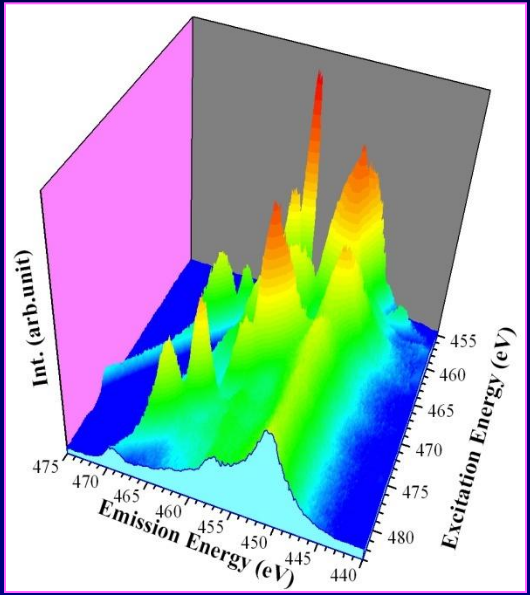


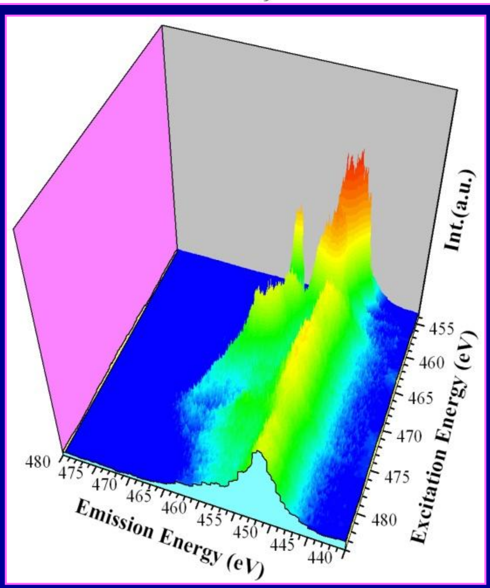
Contour Plot of TiO_2

$L\alpha_{1,2}$: $3d_{5/2}$, $3d_{3/2} \rightarrow 2p_{3/2}$ (452.2 eV)

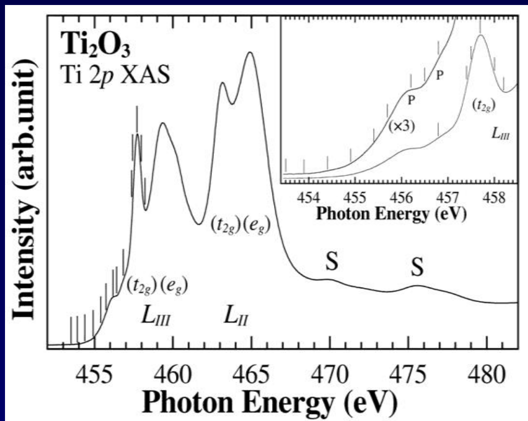
$L\beta_1$: $3d_{3/2} \rightarrow 2p_{1/2}$ (458.4 eV)







Previous results of Ti_2O_3



Ti 2p XAS of Ti_2O_3.

Ti_2O_3

- Nominally $3d^1$ system.
- Strong hybridization between Ti and O.
- Typical Mott-Hubbard insulator (Eg ~ 0.1eV).
- Metal-Insulator transition at about 200 ºC
- Powdered sample.

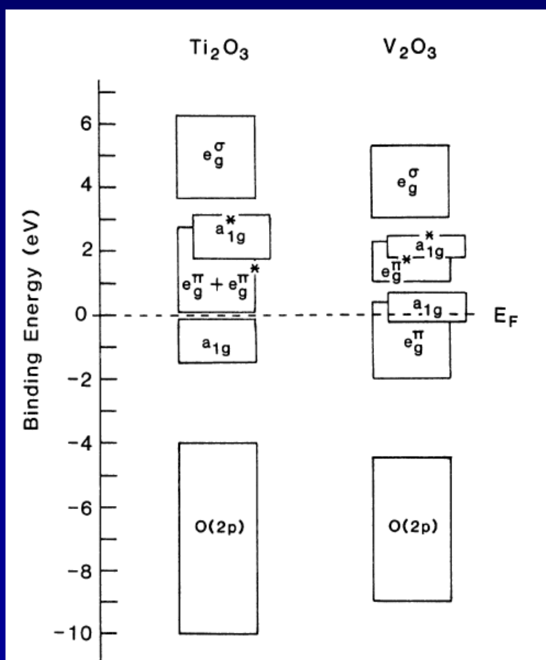
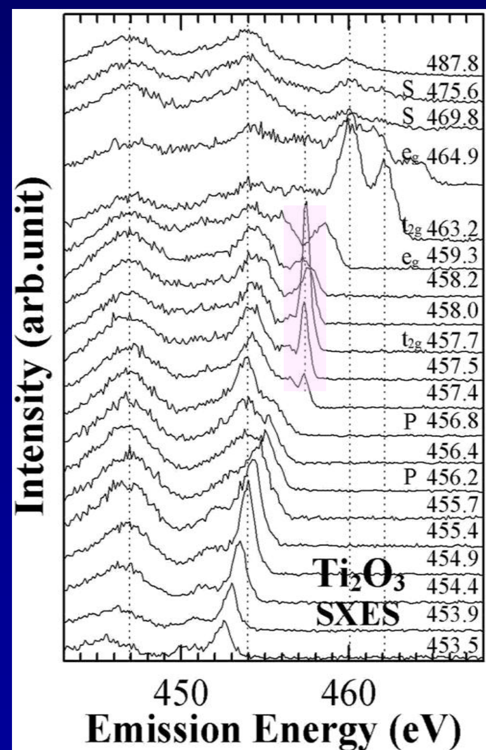
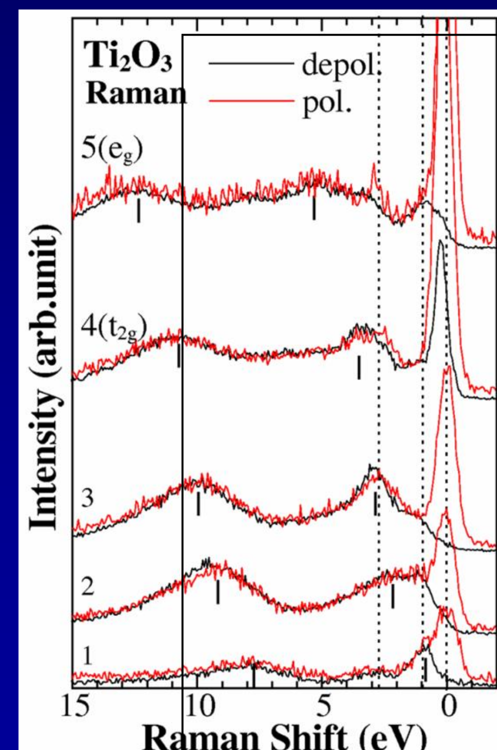


FIG. 1. Empirical band structures for Ti_2O_3 and V_2O_3 (from Ref. 1).

K.E. Smith and V.E. Henrich, Phys. Rev. B38, 5965 (1988)



Ti 2p XES of Ti_2O_3.



Polarization dependence

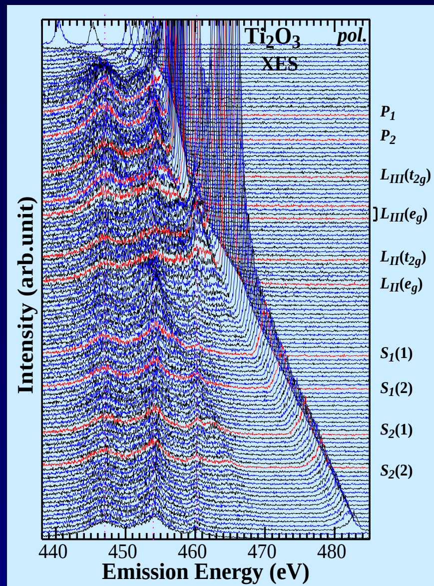
Resonant X-ray Emission and Raman Scattering Spectra of Ti_2O_3

polarized

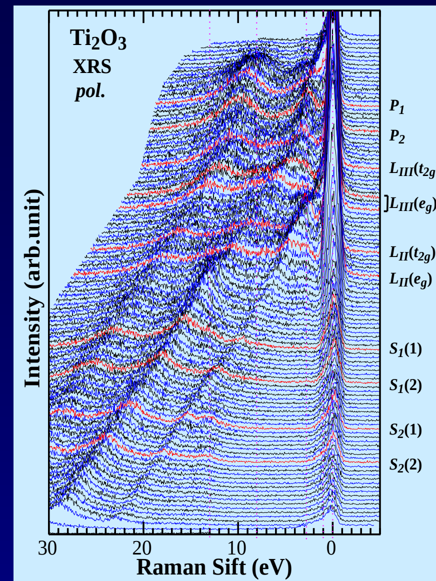
Ti_2O_3:
powder
~ 45K

depolarized

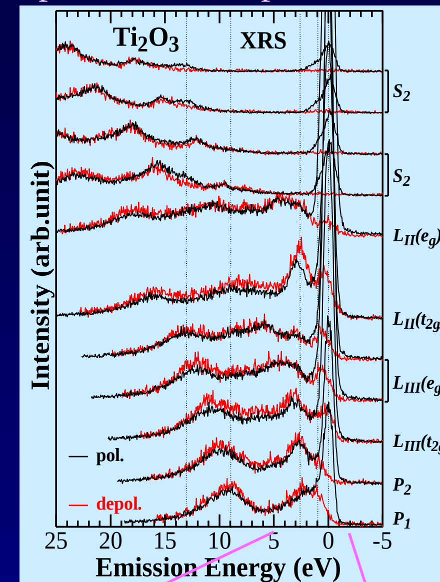
XES

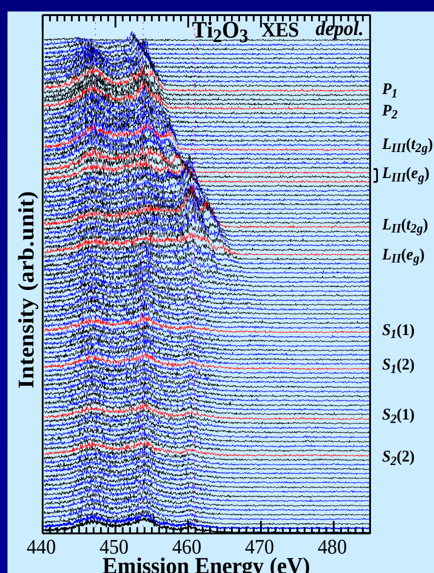


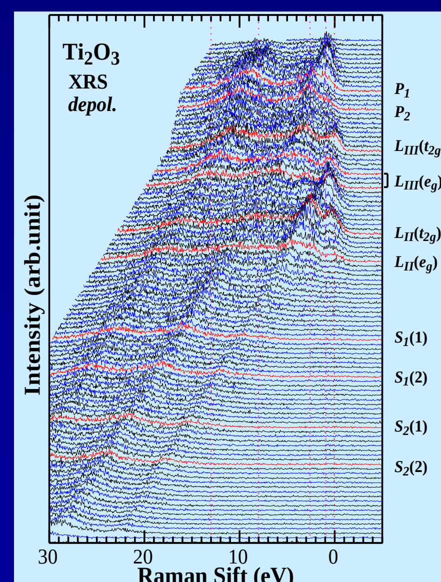
Raman

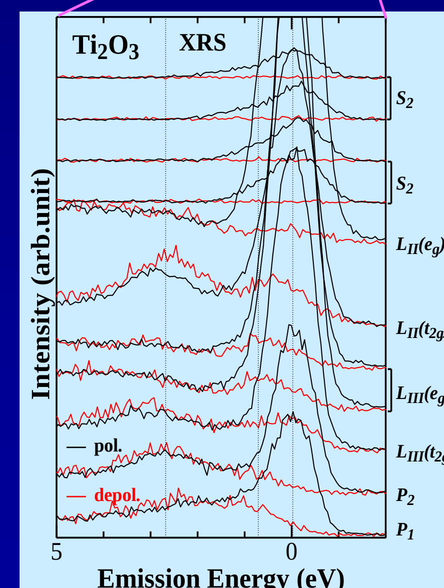


polarization dependence





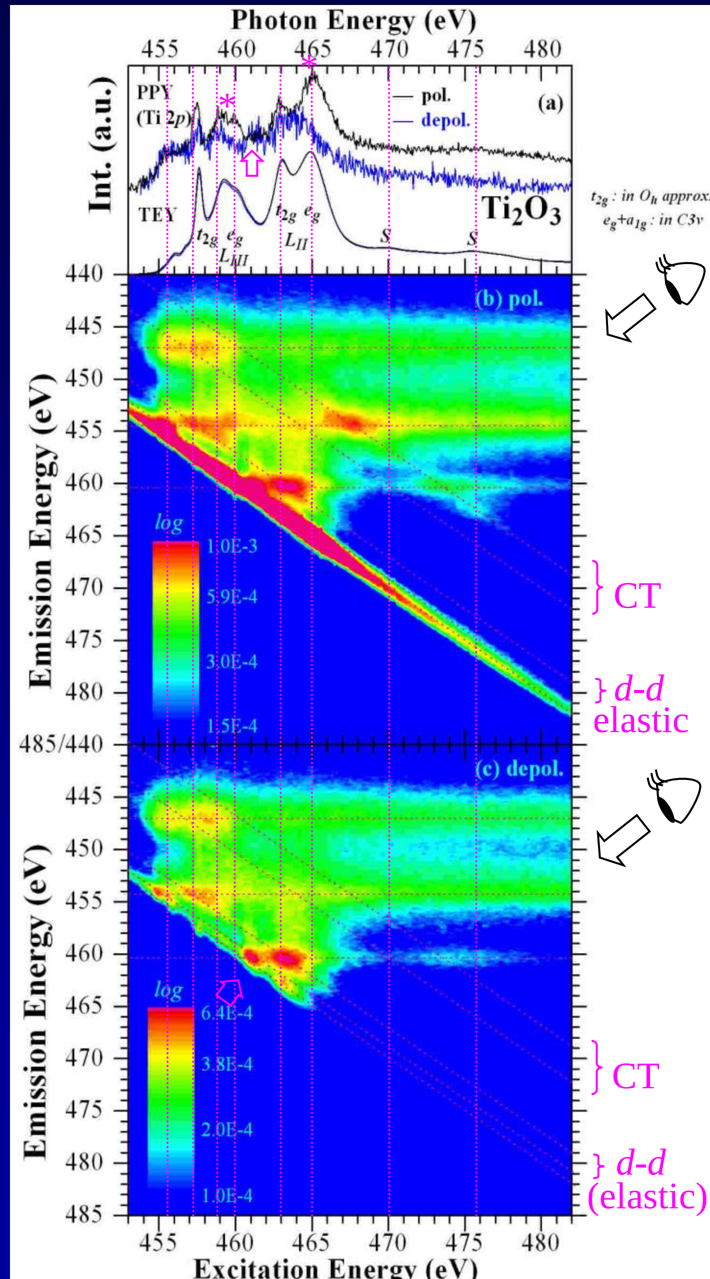




Contour Plot

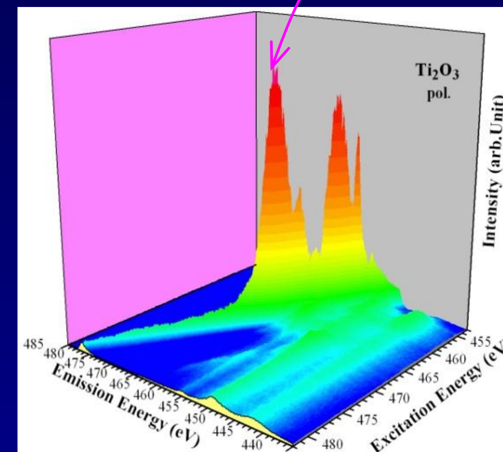
Ti_2O_3
~ 45K

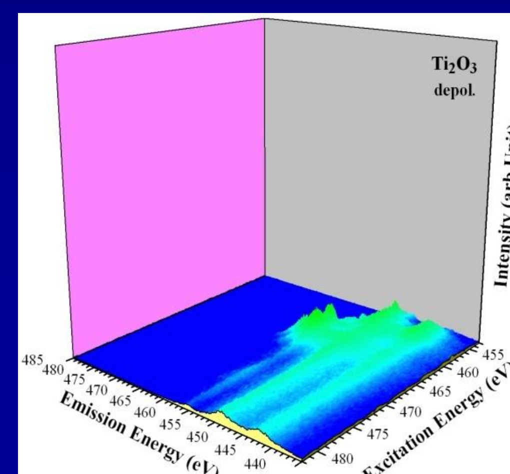
- **Strong *d-d* excitation**
- **Weak CT excitation**
- **Polarization dependence**
  @ e_g excitation (*)
- **Hidden structures ⇨**



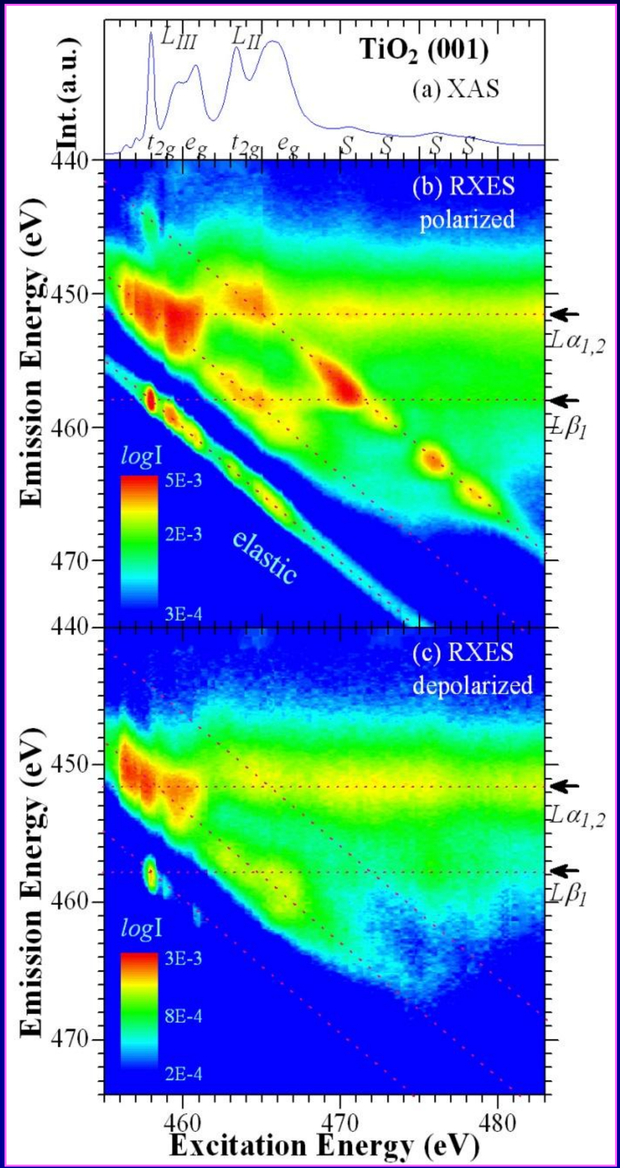
PPY (Partial Photon Yield)
TEY (Total Electron Yield)

Strong elastic peak
→ PPY

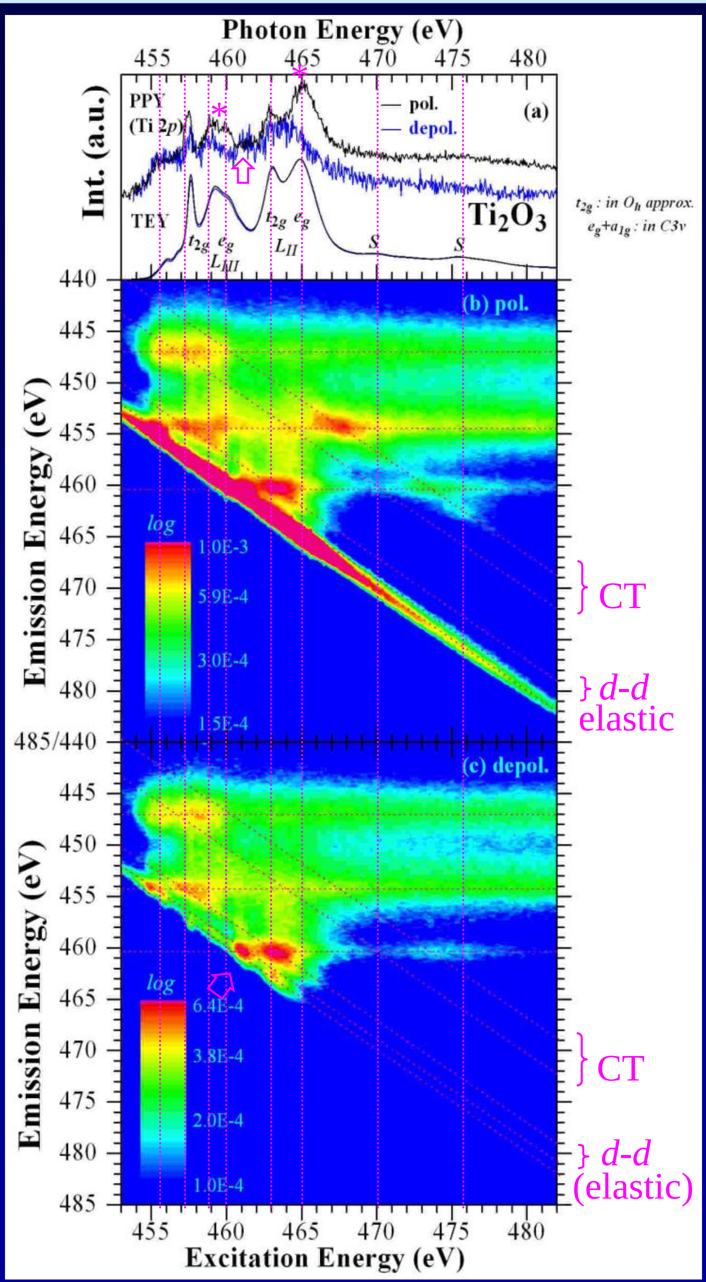




Conmarison



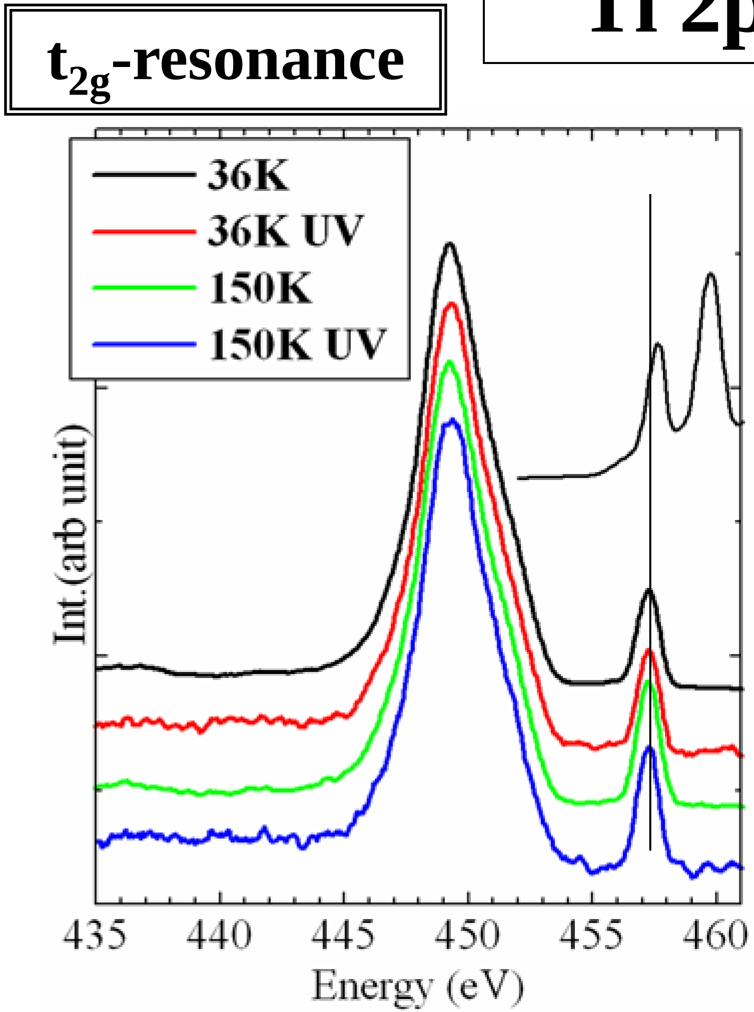
TiO2 (001)
(a) XAS
Int.(a.u.)
(b) RXES polarized
(c) RXES depolarized
Emission Energy (eV)
Excitation Energy (eV)
elastic
logI
5E-3
2E-3
3E-4
3E-3
8E-4
2E-4
Lα1,2
Lβ1

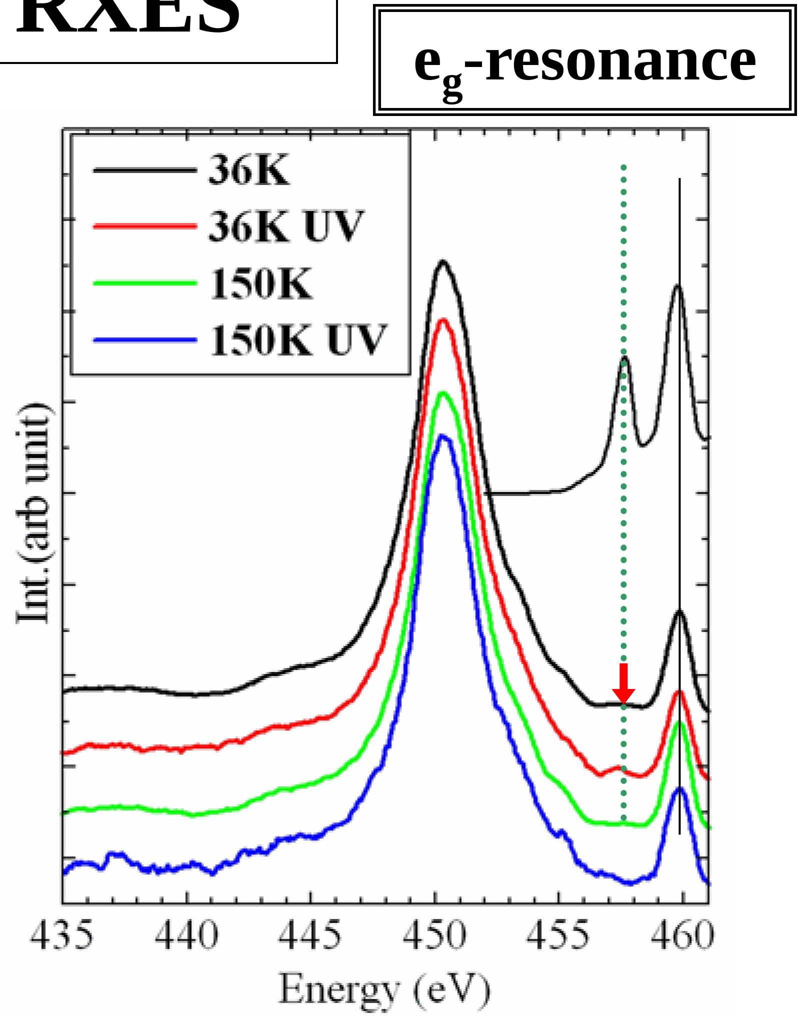


Photon Energy (eV)
PPY (Ti 2p)
TEY
— pol.
— depol.
(a)
Ti2O3
Int. (a.u.)
(b) pol.
(c) depol.
Emission Energy (eV)
Excitation Energy (eV)
log
1.0E-3
5.9E-4
3.0E-4
1.5E-4
6.4E-4
3.8E-4
2.0E-4
1.0E-4
t2g : in Oh approx.
eg+a1g : in C3v
CT
d-d
elastic
CT
d-d
(elastic)

Photo-induced phase transition of$SrTiO_3$ (H.Osawa)

Ti 2p RXES





Only 36 K under UV irradiation, the *d-d* excitation peak (↓) was observed in e_g resonance.

ナノ粒子V酸化物（佐賀大・石渡ら）

PHYSICAL REVIEW B **82**, 115404 (2010)

Unusual low-temperature phase in VO_2 nanoparticles

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[2]*Department of Applied Quantum Physics, Kyushu University, Fukuoka 812-8581, Japan*
[3]*Hiroshima Synchrotron Radiation Center, Hiroshima University, Higashi-Hiroshima 739-0046, Japan*
[4]*Department of Advanced Physics, Hirosaki University, Hirosaki 036-8561, Japan*
(Received 6 June 2010; revised manuscript received 5 August 2010; published 3 September 2010)

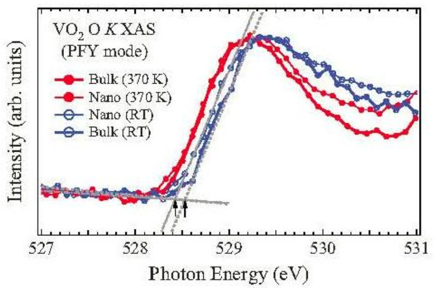

FIG. 6. (Color online) O *K* XAS (PFY) spectra measured using a soft x-ray emission spectrometer for the VO_2 bulk sample (thick solid line with squares) and the nanosample (thin solid line with circles) at 370 K (solid symbols) and at room temperature (open symbols). The fitted straight lines to determine the absorption edges in the low-temperature phases of the bulk and nanosamples are added.

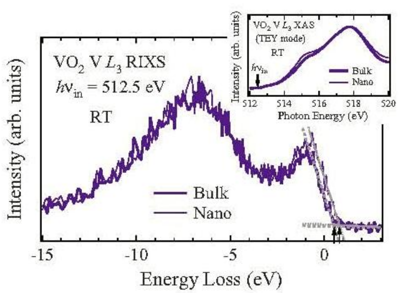

FIG. 7. (Color online) RIXS spectra under 512.5 eV excitation, which is near the V L_3 threshold for the VO_2 bulk sample (thick solid line) and nanosample (thin solid line) at room temperature. The fitted straight lines to determine the energy positions of the lowest *d-d* transitions for the bulk and nanosamples are added. Inset shows V L_3 XAS (TEY) spectra for the VO_2 bulk sample (thick solid line) and nanosample (thin solid line) at room temperature.

Journal of the Physical Society of Japan
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Metal–Insulator Transition for V_2O_3 Powder Observed Using a Soft X-ray Emission Spectrometer

Yoichi ISHIWATA*, Satoshi SUEHIRO, Yasuyuki SOI, Yasuhisa TEZUKA[1], Osamu MORIMOTO[2], and Xu-Guang ZHENG

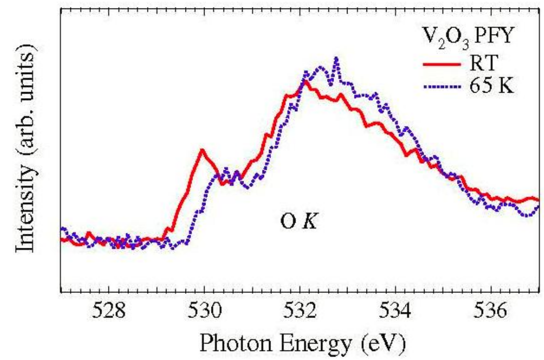


Fig. 4. (Color online) PFY spectra measured using a soft x-ray emission spectrometer for the V_2O_3 powder at room temperature (red solid line) and 65 K (blue dotted line).

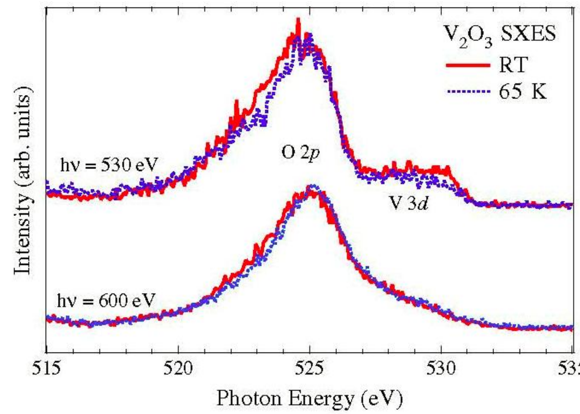


Fig. 5. (Color online) SXES spectra under the excitation of 530 eV near the O *K* threshold and 600 eV away from the resonance region for the V_2O_3 powder at room temperature (red solid line) and 65 K (blue dotted line).

今後の展望1

- 励起光の可変偏光化
　（最重要）
- 装置（精密機器）の固定（＋温調）

→ 測定効率の向上
データの信頼性向上
[偏光]測定の簡素化

- 励起状態の測定：　磁場下、電場下、光（レーザー）照射 etc

- 超高真空化　→　光電子との同時計測、表面･界面

- 低温化　→　光誘起相転移等低エネルギーの変化

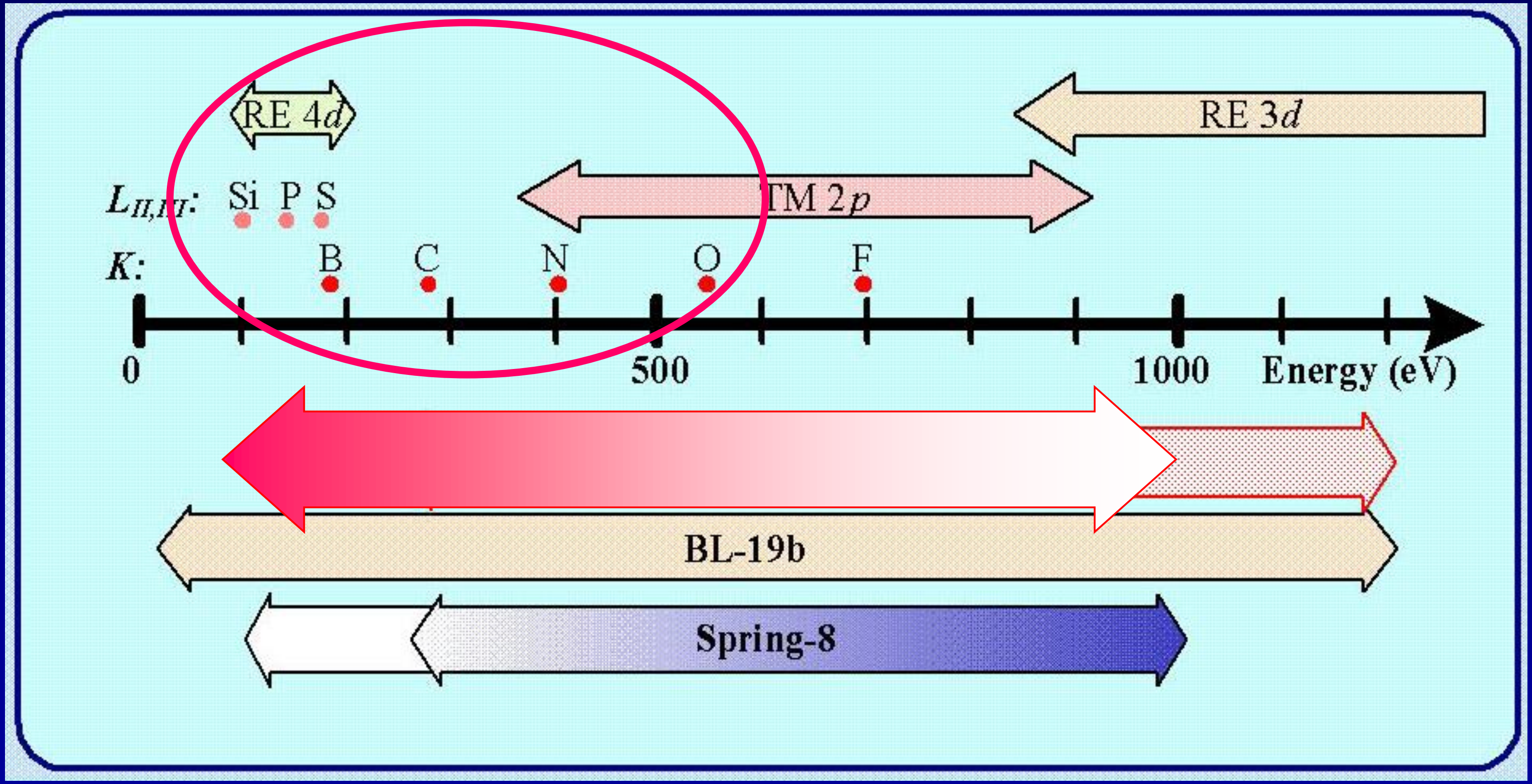
今後の展望2

- エネルギー領域の拡大 ➡ 軽元素（B, N, C, Si, etc）の測定

  BL-2c ： 250～1200 eV ➡ 90～1200 eV（30~1000 eV）

  BL-19b： 10～1200 eV（分解能悪い、老朽化）

  Spring-8：200～1000 eV（270 eV以上で可変偏光）



今後の展望3

- 高分解能化

  低エネルギーの素励起の測定

  結晶場（*d*-*d*）励起、phonon、orbitoron、etc

- 時間分解 ⇨ SP8で開始。PFでもある程度の投資で可能。

- 角度分解（q-依存性）

- 偏光依存性（発光の偏光解析）

  素励起の対称性

- 空間分解

  マッピング

Fin