Photo-induced carrier dynamics of charge glass using time-resolved spectroscopy

2024 Mid-term report meeting

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Contents

Time-resolved spectroscopy

What is Time-resolved spectroscopy?

A method to **investigate the transient response** of electrons using **laser pulses**

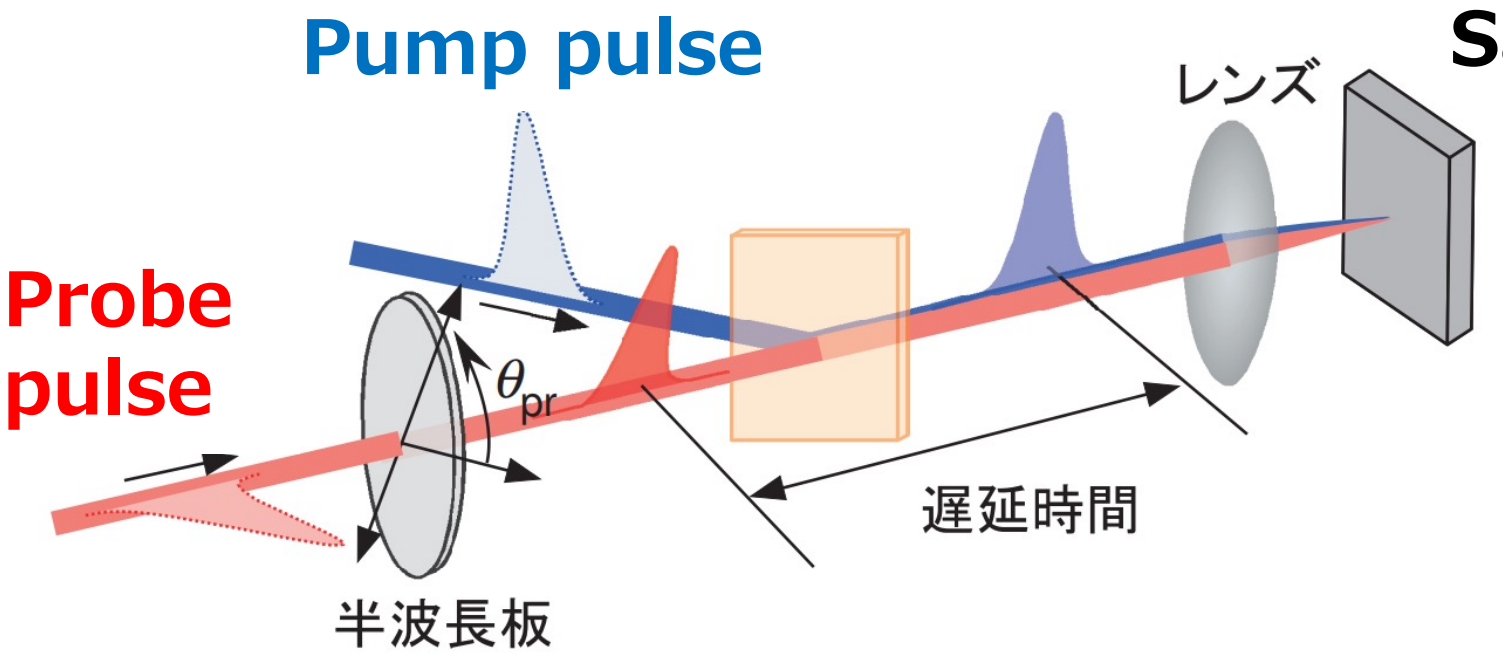
Ex) **emission, absorption**

Why laser pulse?

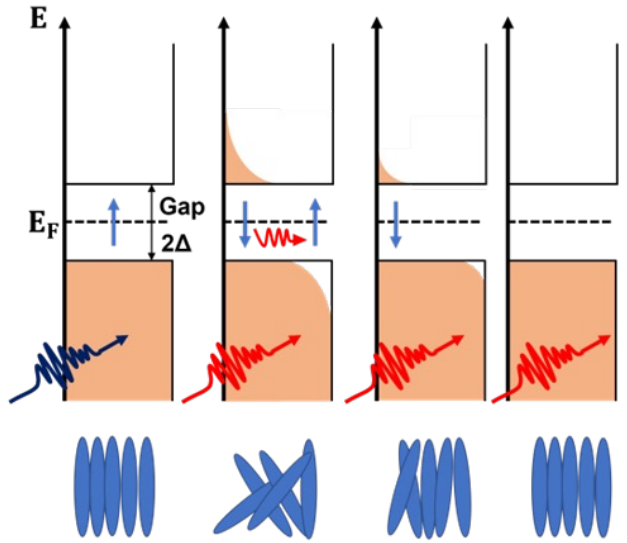
Spatiotemporally controlled pulses enable **high time-resolution**

Especially, we use **Pump-probe spectroscopy**

Pump-probe spectroscopy

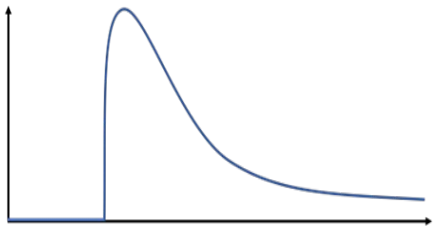


Sample



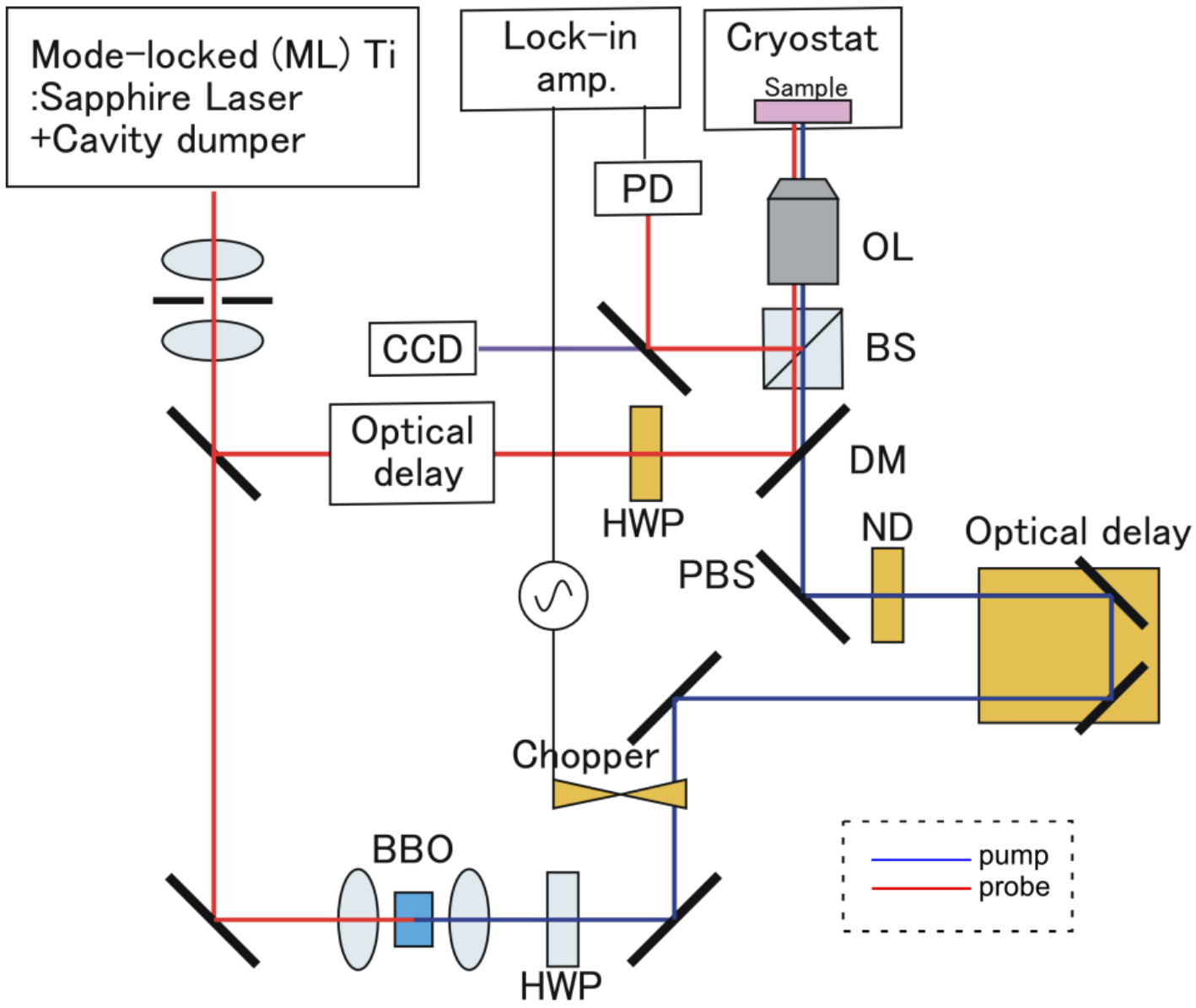
電荷秩序
模式図

Transient reflectivity



Delay time

Experimental system



Background

liquid phase(disordered)

cooling Generally, **a phase transition to solid phase(ordered),**
But in a special condition, **freeze randomly**

This is what we call glass

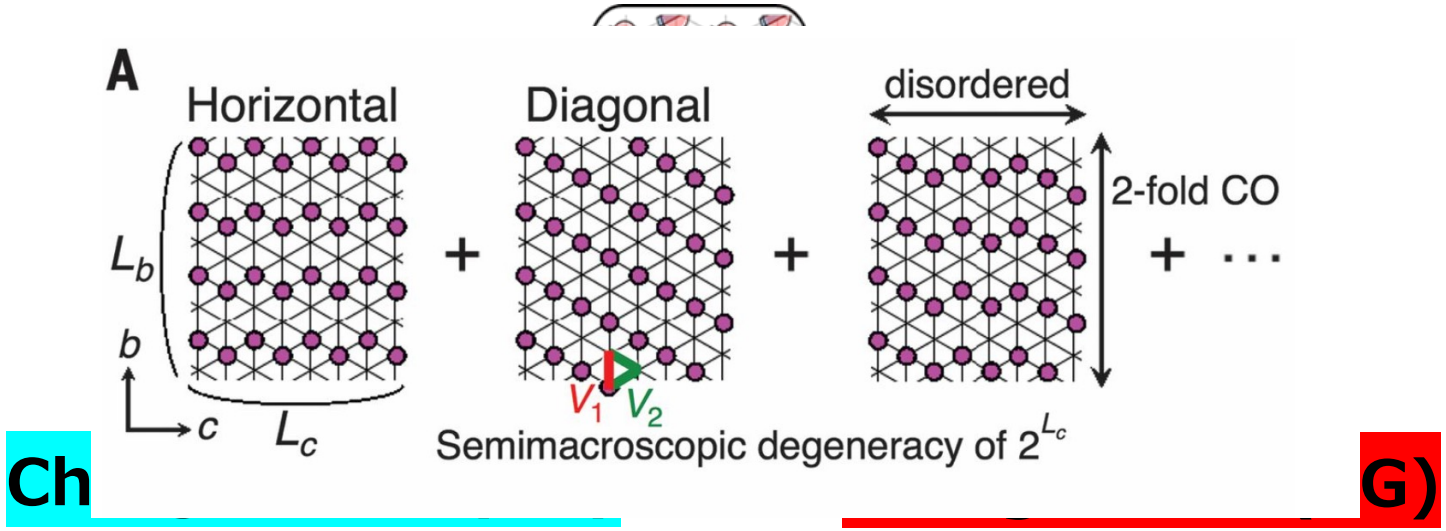
Glass has both liquid-like disorder and solid-like rigidity

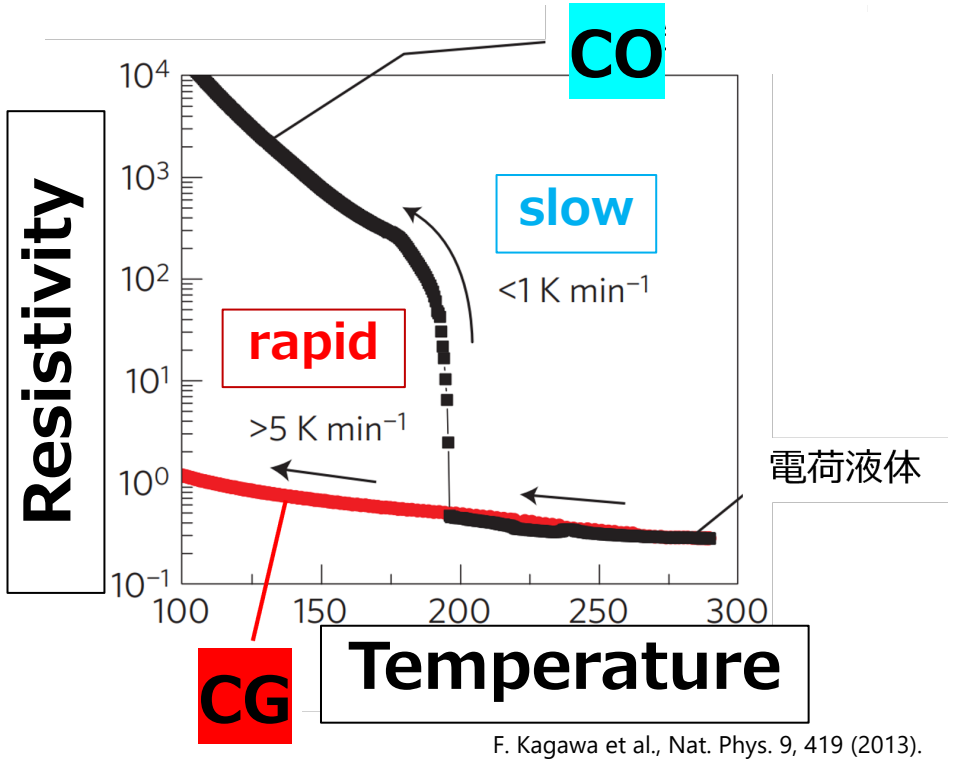
The mechanism of glass formation is said to be one of **the greatest mysteries** in physics

Background

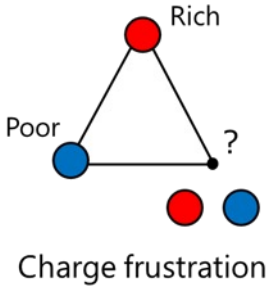
In a organic matter family,

Electronic systems have also been found to be vitrified





F. Kagawa et al., Nat. Phys. 9, 419 (2013).



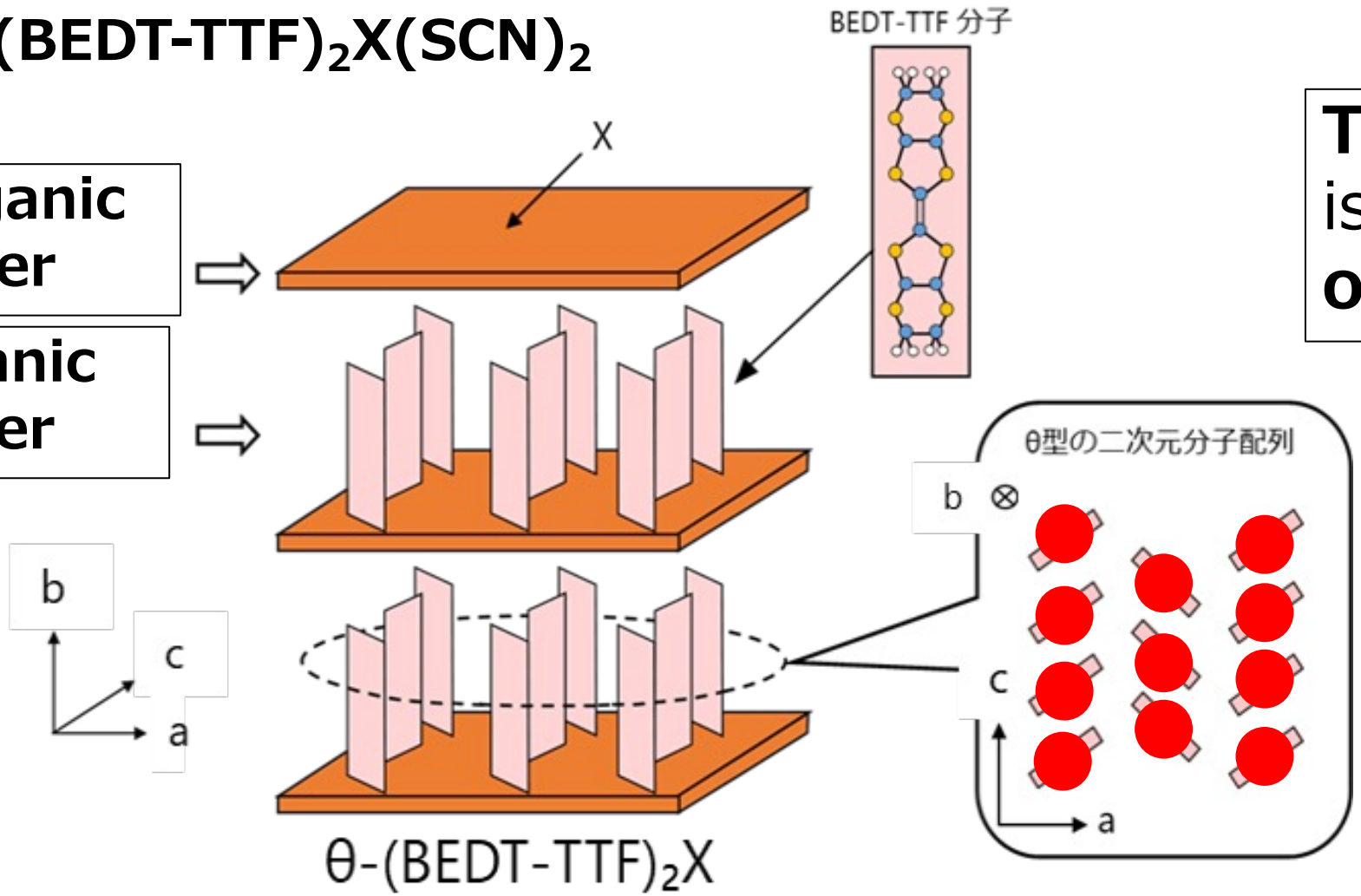
Frustration(third vertex has charge or not)**makes glassy state**

Background

θ-$(BEDT\text{-}TTF)_2X(SCN)_2$

Inorganic layer

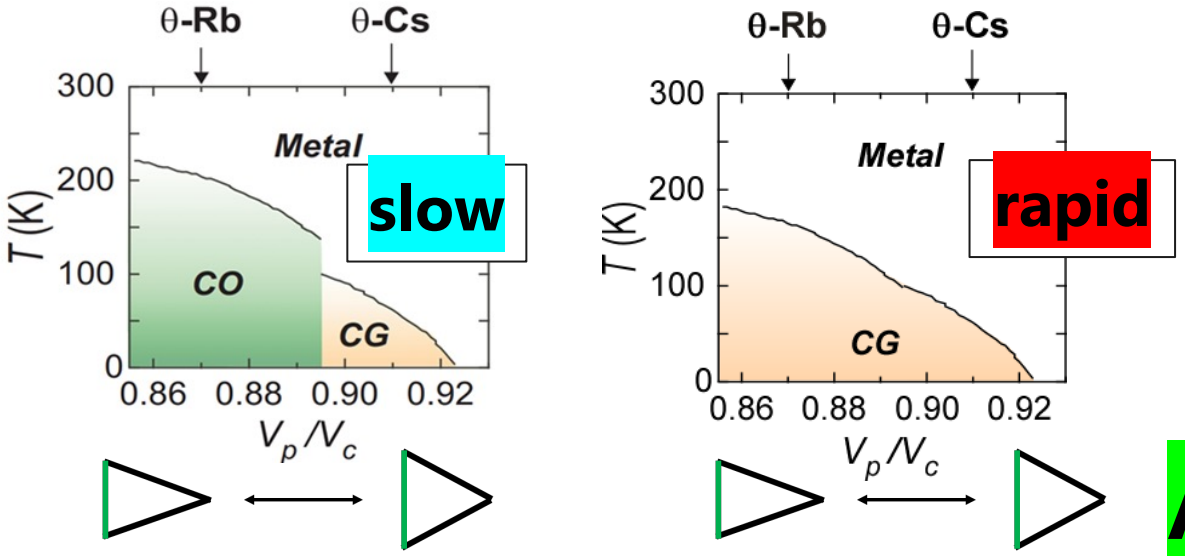
Organic layer

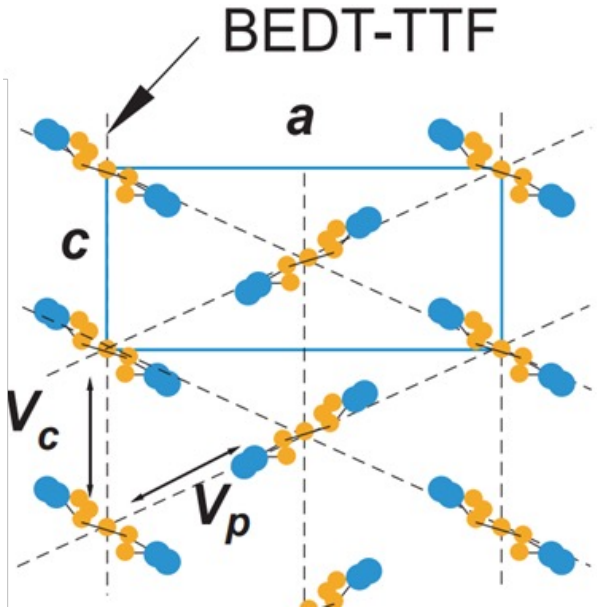


Triangular lattice is formed in the **organic layer**

Background

- **θ-Rb**: **Charge order**(**CO**) in slow cooling
  Charge glass(**CG**) in **rapid cooling**
- **θ-Cs**: **Charge glass**(**CG**) regardless of cooling rate



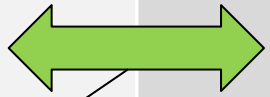


The closer to an equilateral triangle, the stronger its frustration

Are there differences between different frustrated glass state?

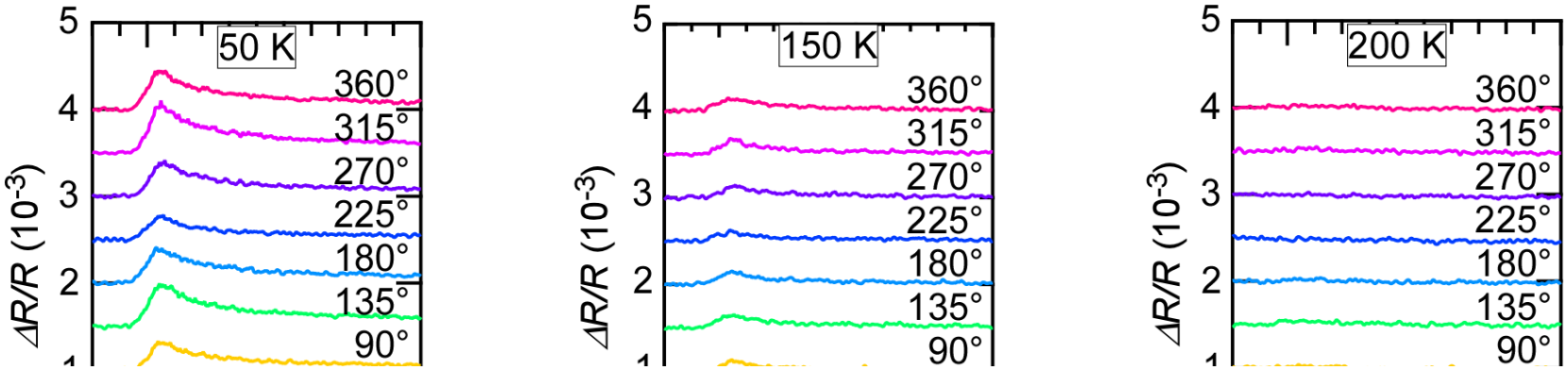
Background

Cooling rate	θ-Rb :weakly frustrated	θ-Cs :strongly frustrated
Slow	CO (K. Nakagawa et al, Phys. Rev. Research 5, 013024 (2023))	CG
rapid	CG	CG (K. Nakagawa, S. Tsuchiya, H. Taniguchi, and Y. Toda Phys. Rev. Research 5, 013024 (2023))



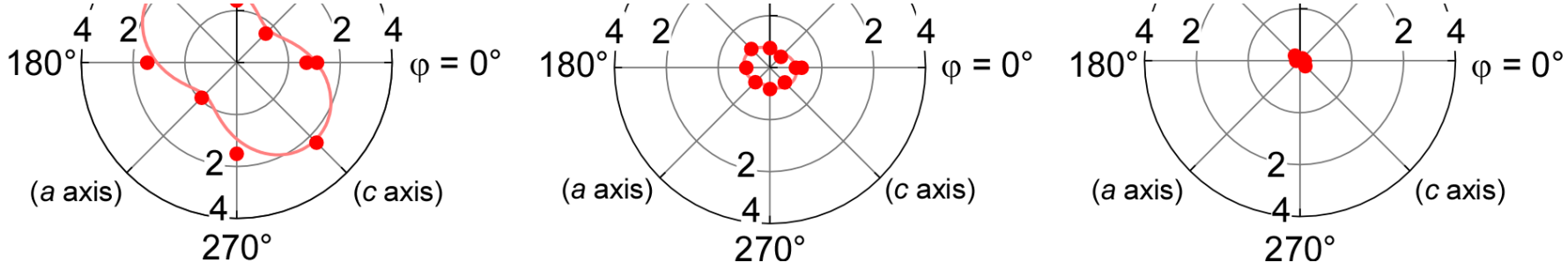
Investigate the difference Between CG

Result

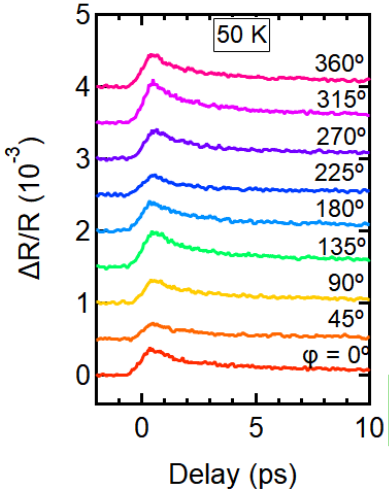


With decreasing temperature…

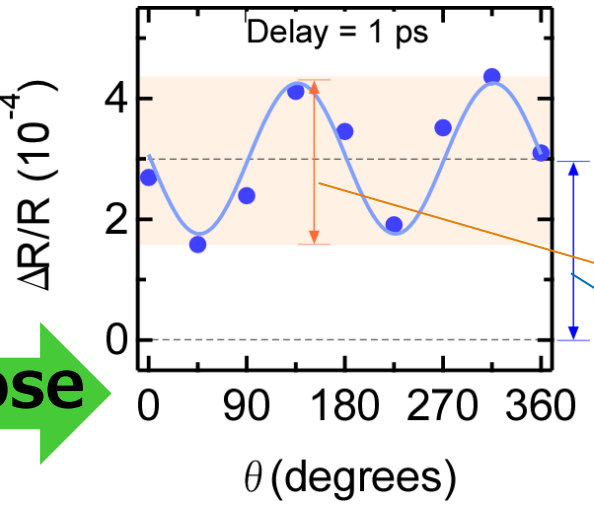
The response increased and polarization dependence emerged



Result



decompose



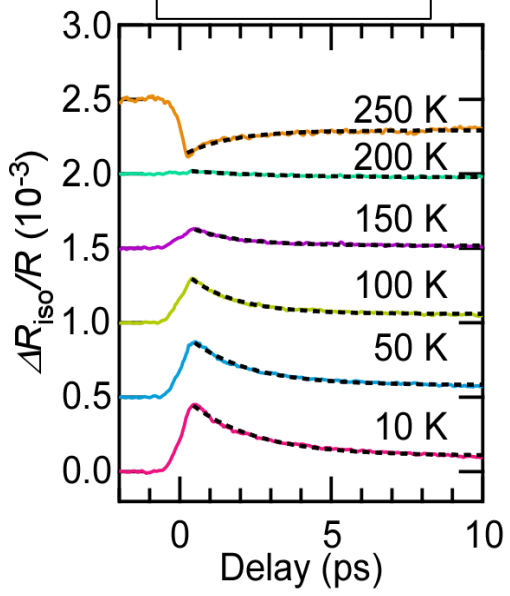
$$\frac{\Delta R}{R} = \frac{\Delta R_{iso}}{R} + \frac{\Delta R_{ani}}{R}\cos(2\theta - 2\theta_0)$$

$$A exp\left(-\frac{t}{\tau}\right) + C$$

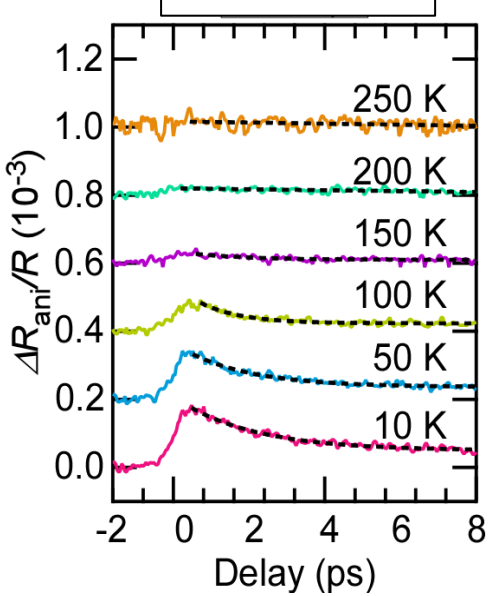
fitting

A: transient signal amplitude
τ: relaxation time
C: component with infinite relaxation time

$\Delta R_{iso}/R$

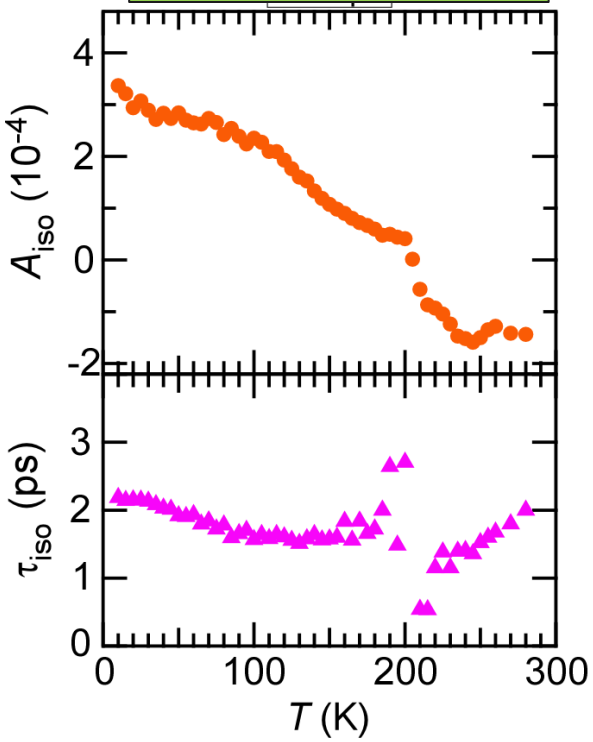


$\Delta R_{ani}/R$

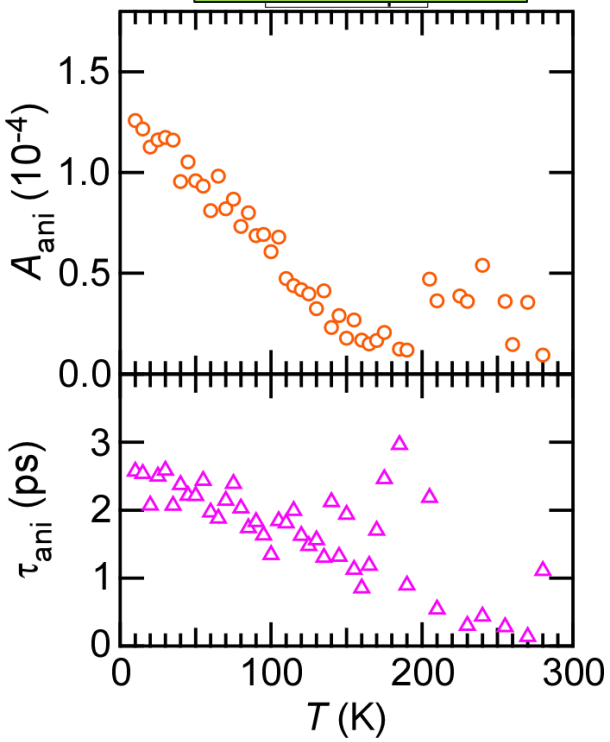


Result

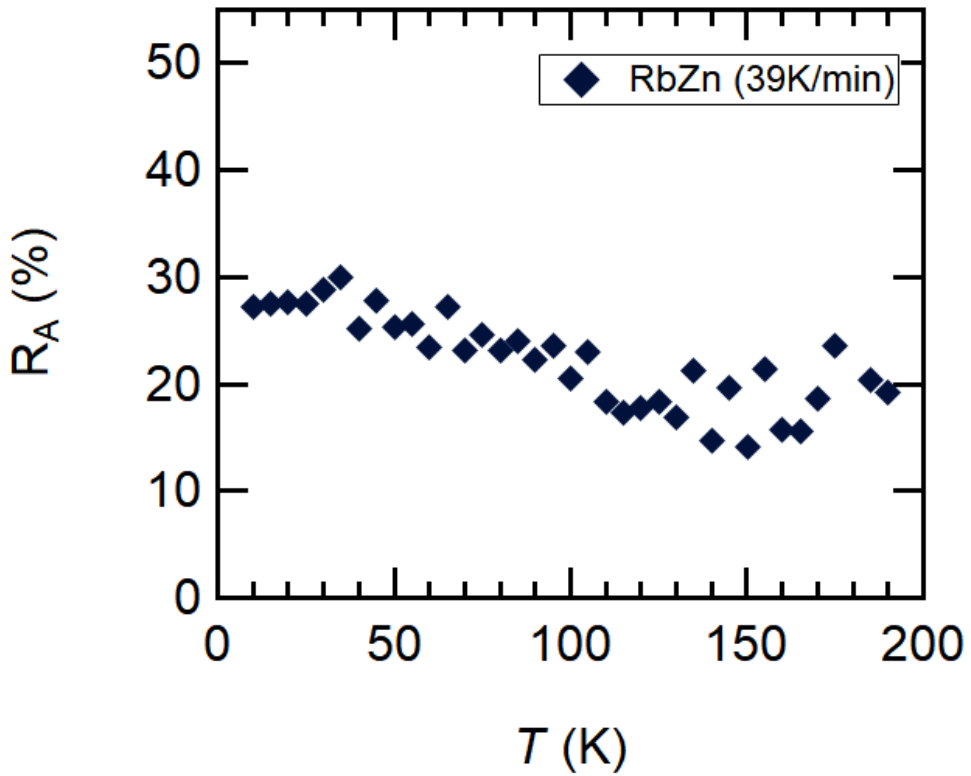
anisotropic



isotropic



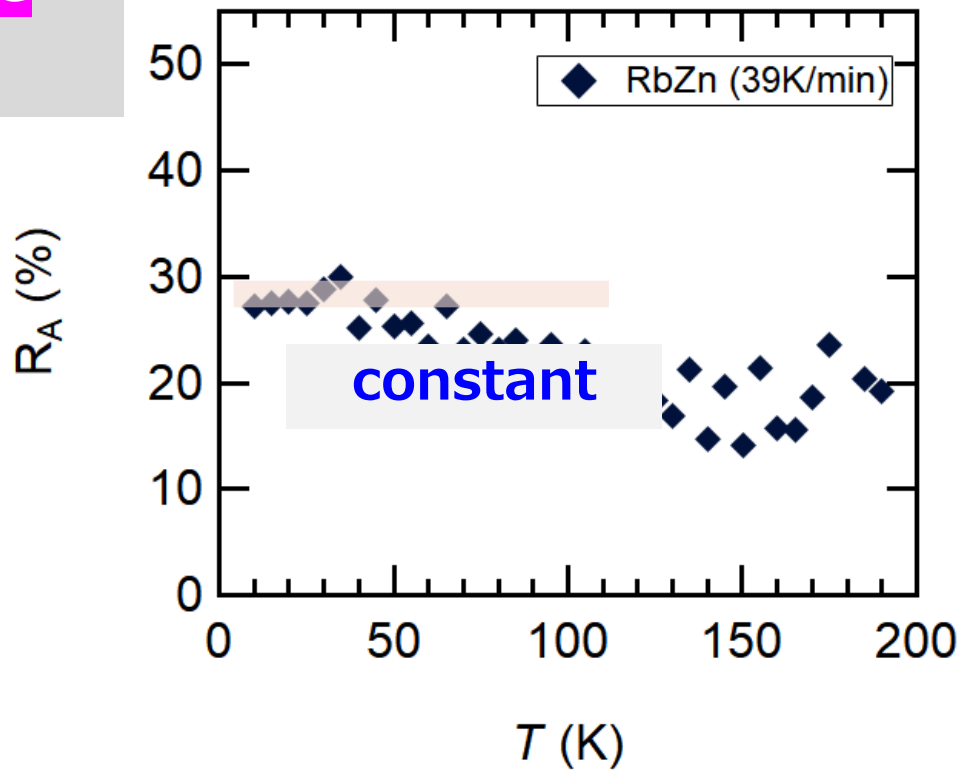
$$R_A = \frac{A_{ani}}{A_{ani} + A_{iso}}$$

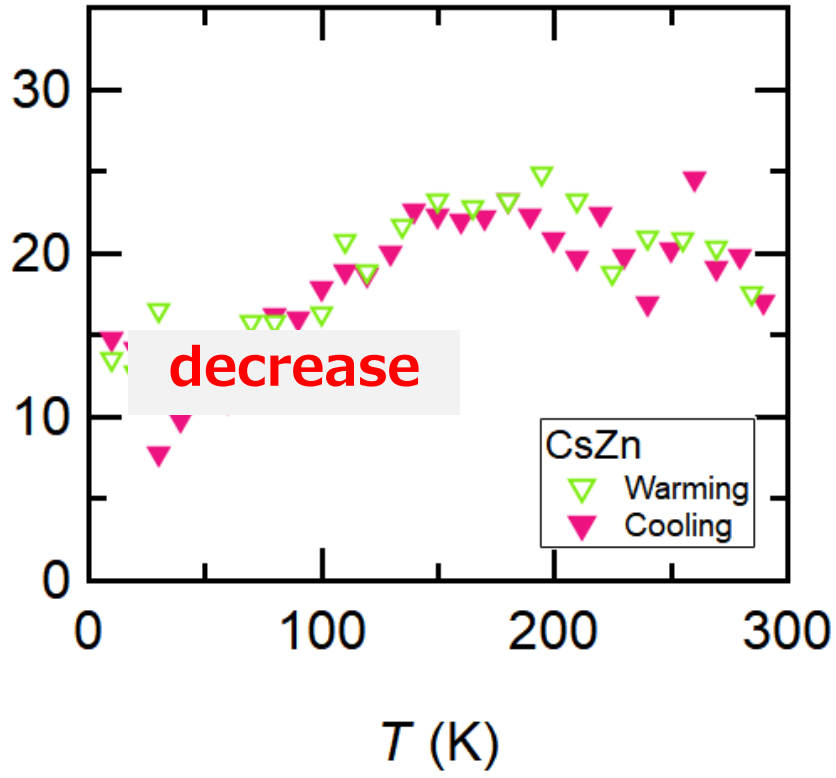


Both increased with decreasing temperature

Discussion

	θ-Rb	θ-Cs
slow	CO	CG
rapid	CG ⟺	



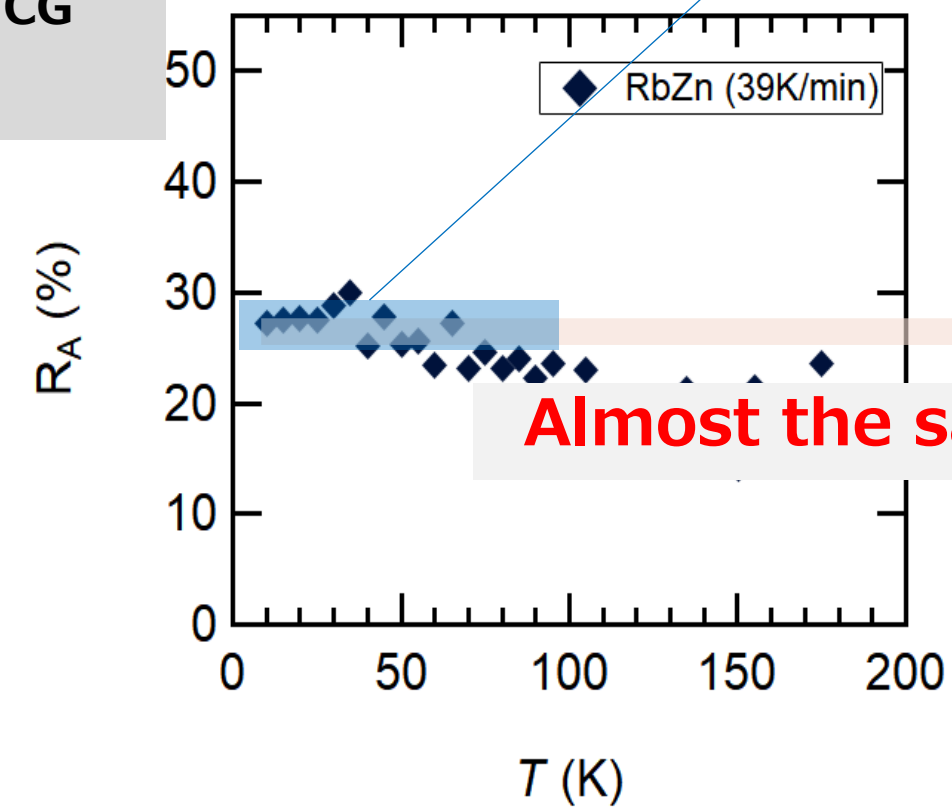


weak ⟸ **frustration** ⟹ **strong**

Discussion

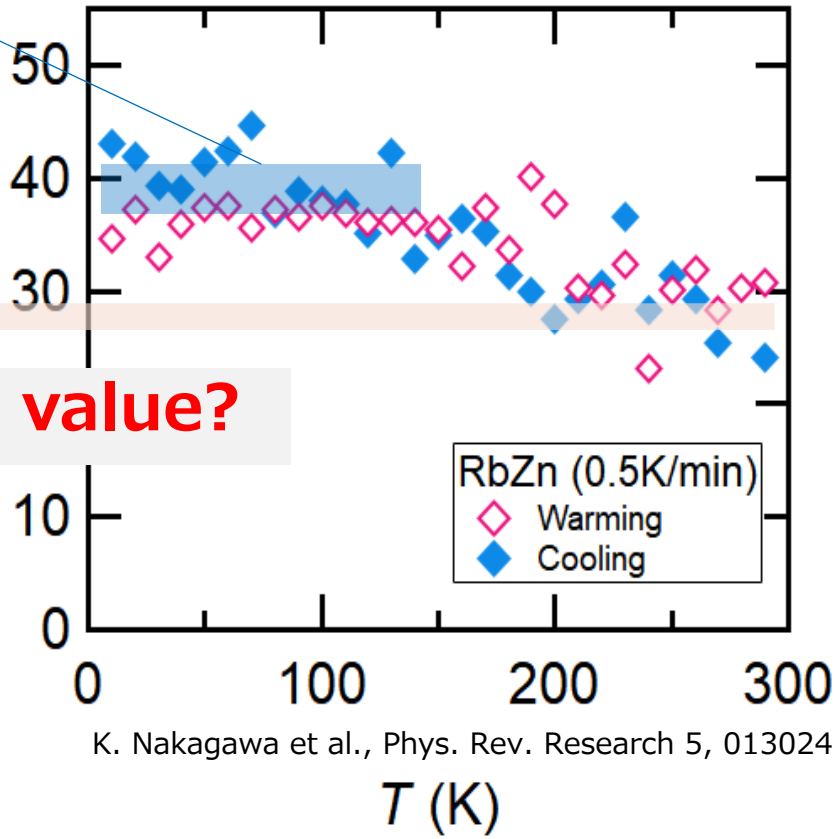
	θ-Rb	θ-Cs
slow	CO	CG
rapid	CG	

constant



CG

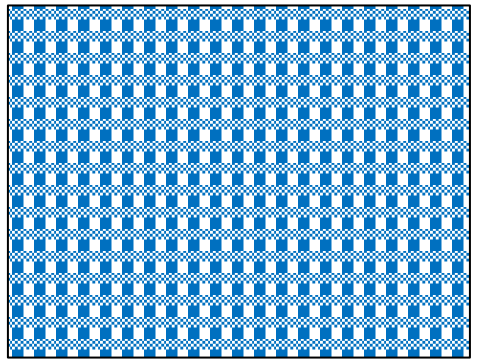
Almost the same value?



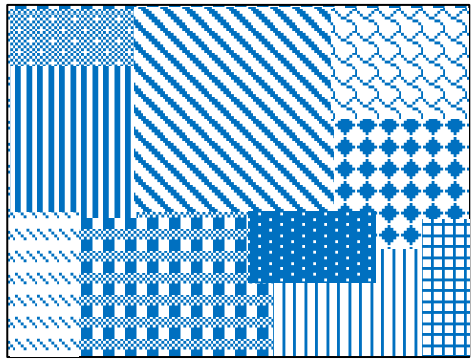
CO

K. Nakagawa et al., Phys. Rev. Research 5, 013024 (202

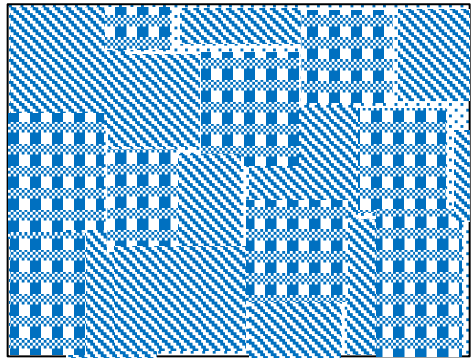
Discussion



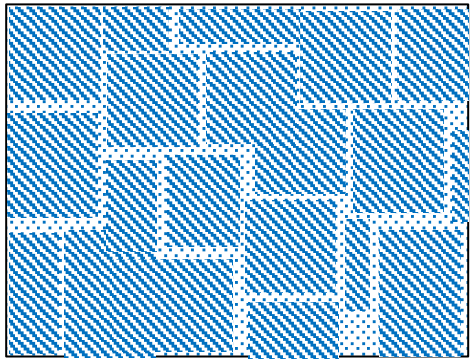
CO



Conventional glass



Cs's CG?



Rb's CG?

:most stable order pattern

:metastable order pattern

In θ-Rb(weakly frustrated), both isotropic and anisotropic component increased

Qualitatively similar to CO

θ-Rb's CG has anisotropic dynamics!

Shortrange CO domain has metastable order ?

Summary

- **Anisotropy of photo-induced carrier dynamics depends on lattice frustration**

  → Electronic system **with different frustration** produce **CG with different properties**

- **CG research is still in the stage of basic research, and we have no clear application**

- **But it shows interesting physical properties (like negative resistance) and drawing attention**

- **Possibly be clue to unraveling the mystery of glass**

Self Introduction

- **Tatsuya Sugioka/杉岡達哉**
- **Time line**

  2002.2 :born in Hyogo

  -2020.3 :Rakusei(洛星) high school in Kyoto

  -2024.3 :Hokkaido Univ. applied physics

  2024.4- :Ando Lab.

- **My Hobby : traveling, watching baseball, stargazing**