GeSb thin films: read-write optical data storage on the subnanosecond time scale

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Javier Solís
John Paul Callan
Chris Roeser
Eric Mazur

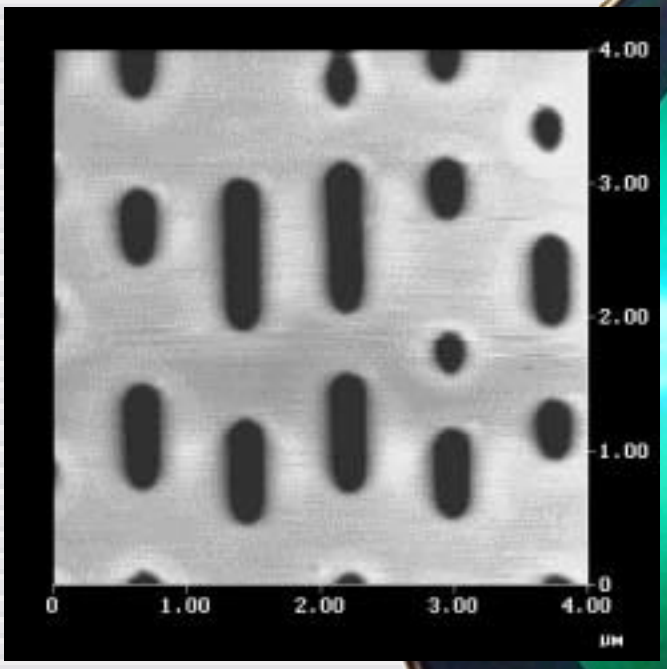
Ultrafast Electronics and Optoelectronics
Lake Tahoe, 11 January 2001

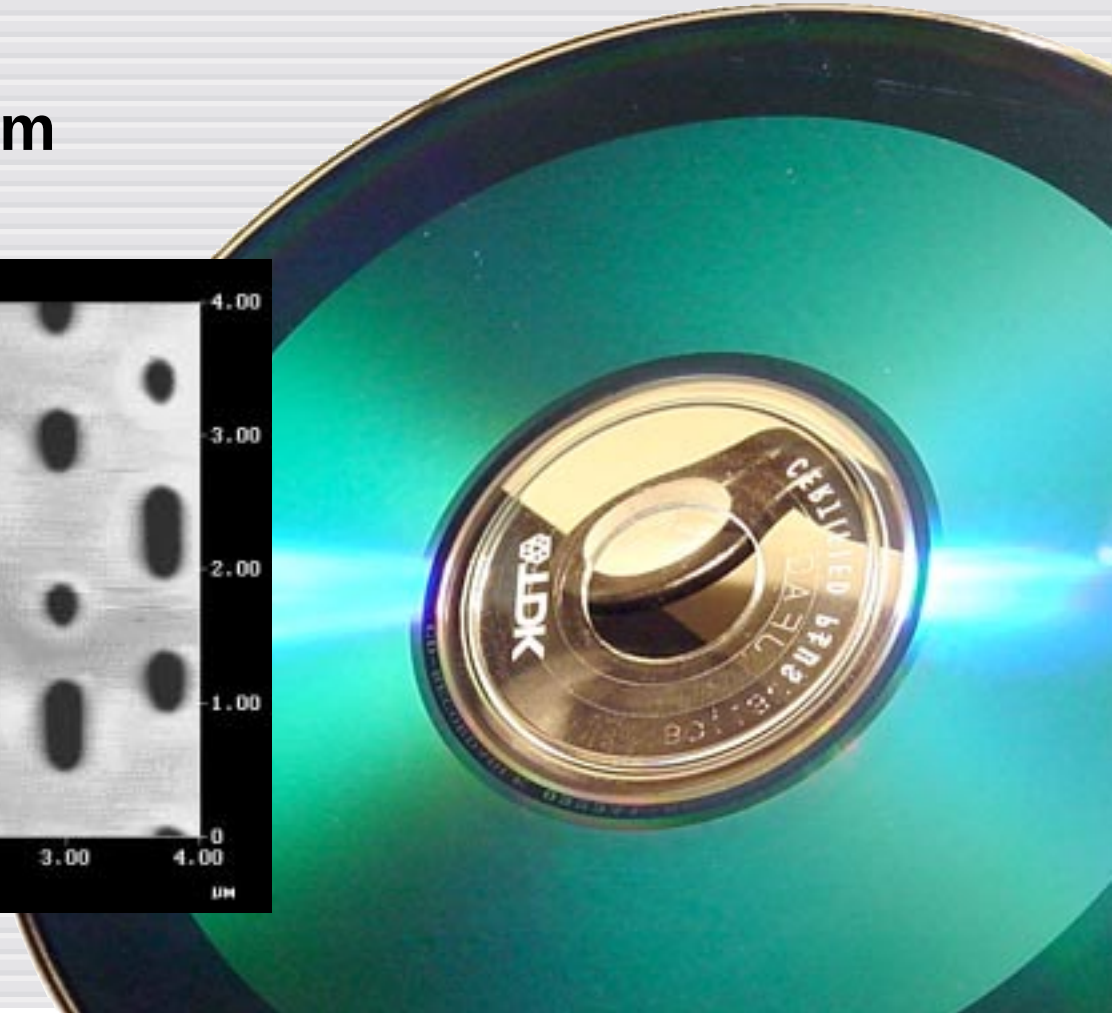
Introduction

- **explosive demand for data storage**
- **10^{20} bits currently**
- **optical data storage: from 680 Mb to 4.7 Gb**

Introduction

- bit length: 0.4 μm
- track spacing: 0.74 μm





Introduction

- **GeSbTe phase-change rewritable medium of choice**
- **high fluence: amorphize (write)**
- **low fluence: crystallize (erase)**

but... crystallization slow!

Introduction

VOLUME 81, NUMBER 17 PHYSICAL REVIEW LETTERS 26 OCTOBER 1998

Dynamics of Ultrafast Phase Changes in Amorphous GeSb Films

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(Received 24 February 1998)

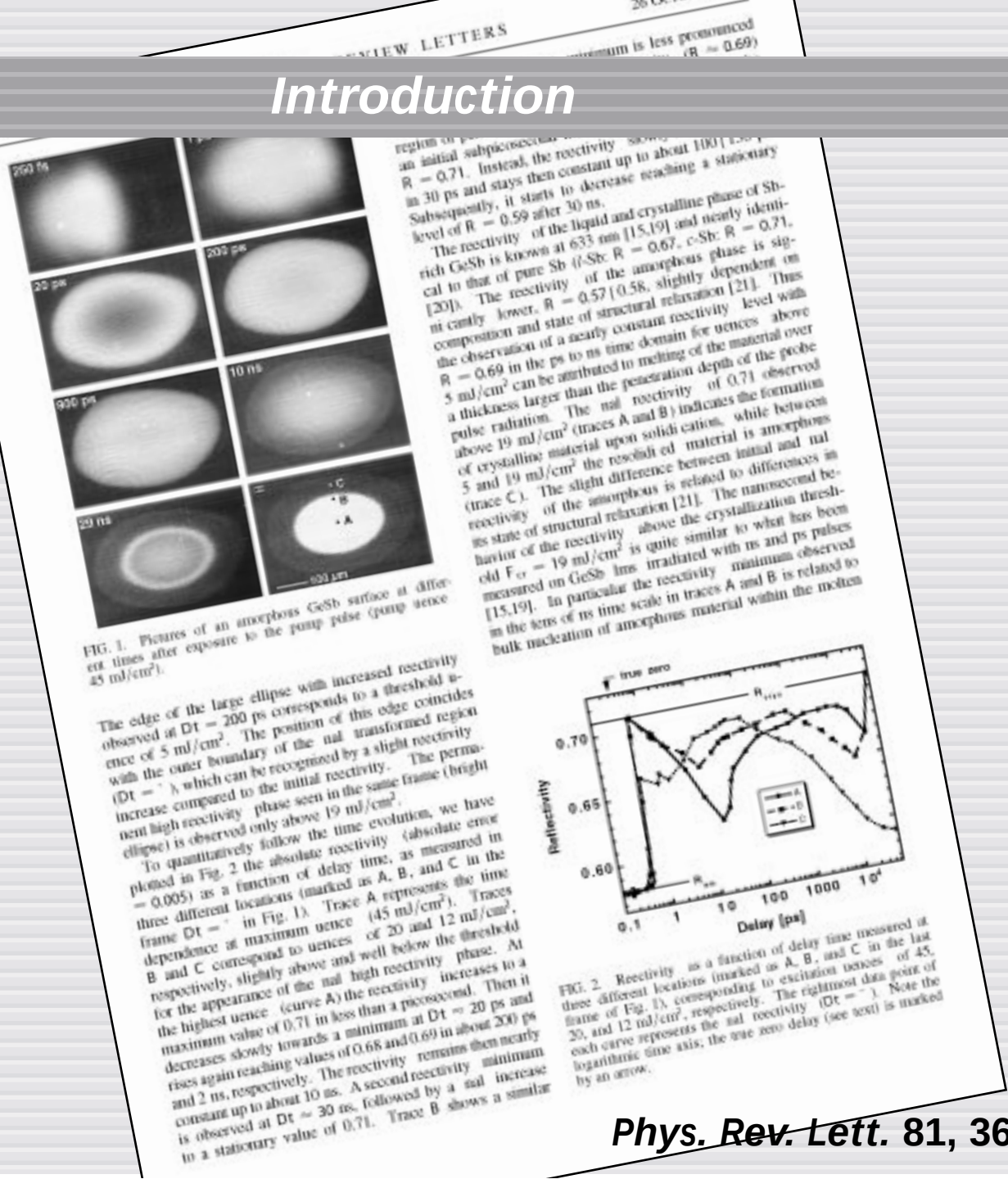
Time resolved imaging has been used to analyze structural transformations induced by intense 100 fs laser pulses in amorphous GeSb films. Above a threshold of 19 mJ/cm^2 the data show the formation of a transient nonequilibrium state of the excited material within 300 fs. The results are consistent with an electronically induced, amorphous-to-crystalline phase transition. [S0031-9007(98)07514-0]

PACS numbers: 61.80.Ba, 61.43.Dq, 68.35.Bs, 68.35.Rh

The existence of nonthermal, ultrafast phase transitions after strong femtosecond laser excitation has been demonstrated in several materials such as silicon [1–3], gallium arsenide [3–6], indium antimonide [7], and carbon [8]. It is accepted that such transitions are induced by a softening of the lattice structure due to the generation of a very high density electron-hole plasma, as first proposed by Van Vechten [9]. Most of the experimental and theoretical [10–13] has concentrated on the solid-to-liquid ... of the above mentioned materials. ... the existence of an ... nonther-

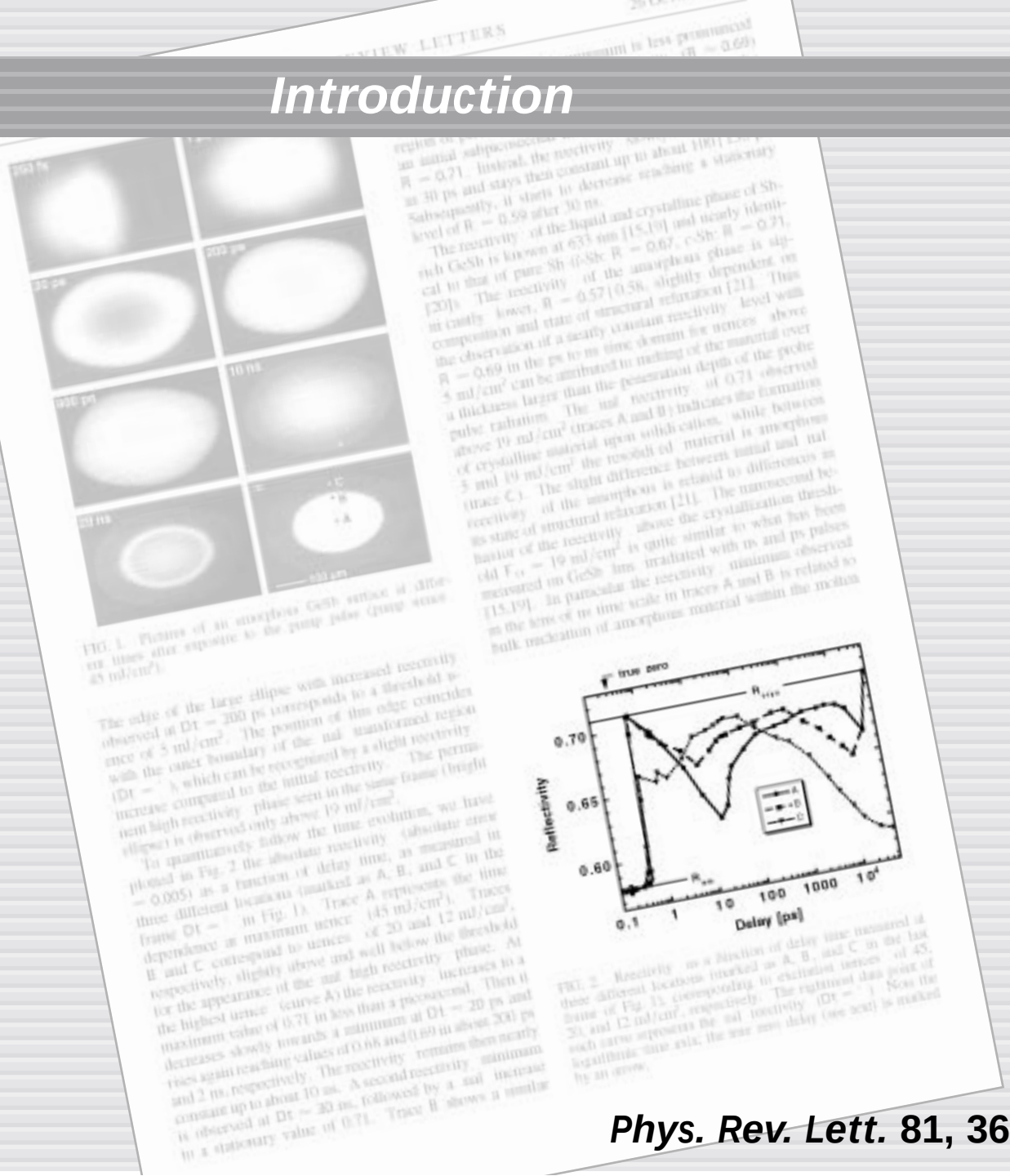
optical microscope and provides snapshot pictures of the excited surface with 100 fs time resolution. The optical micrographs are recorded with the help of a charged coupled device detector in conjunction with a computer controlled frame-grabber. Since a single laser pulse induces permanent structural changes of the irradiated area the sample is moved between two consecutive exposures. A series of pictures, covering the entire period from the initial deposition of the laser energy (pump fluence 45 mJ/cm^2) to the appearance of the final structural modifications, is shown in Fig. 1. The contrast of the images has been enhanced for reproduction purposes and ... thus Fig. 1 does not provide a quantitative measure ... of the reflectivity. Because of the large ... probe (45°), the actual de... the horizo...

Introduction



Phys. Rev. Lett. **81, 3679 (1998)**

Introduction



Phys. Rev. Lett. **81, 3679 (1998)**

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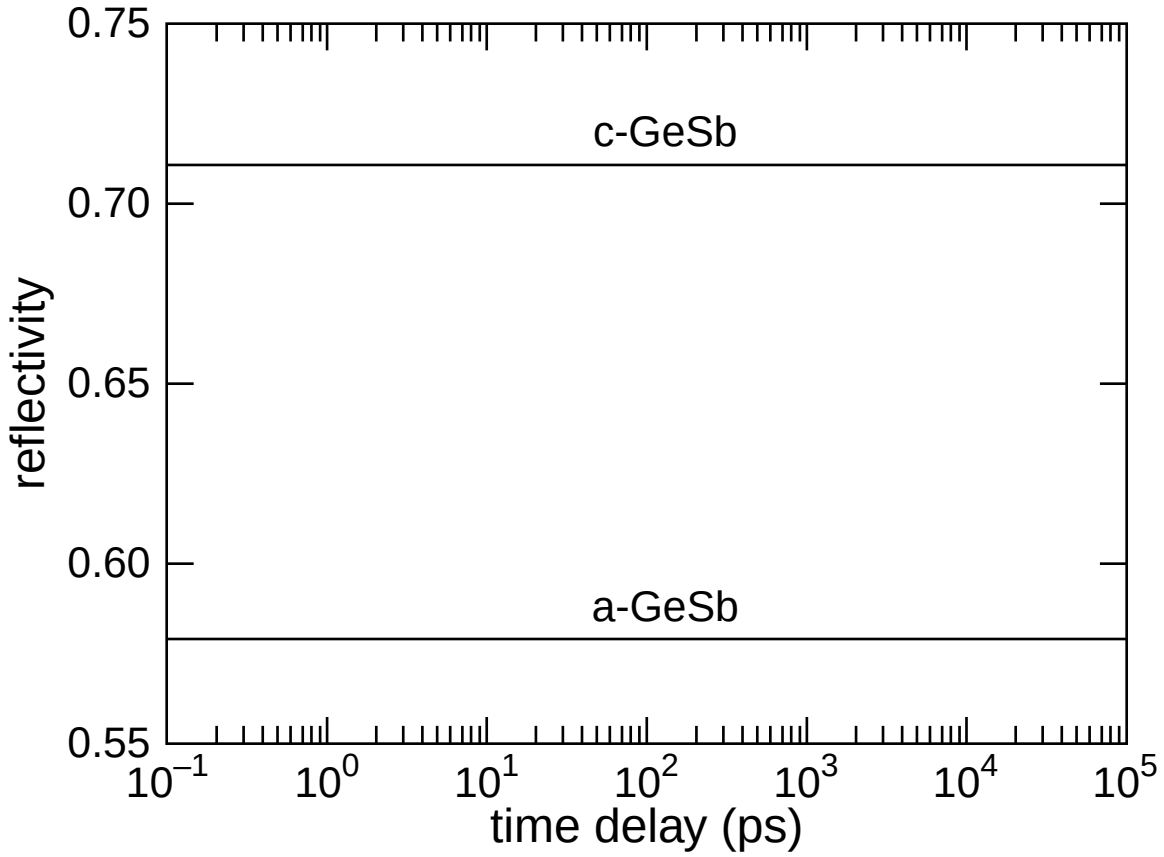

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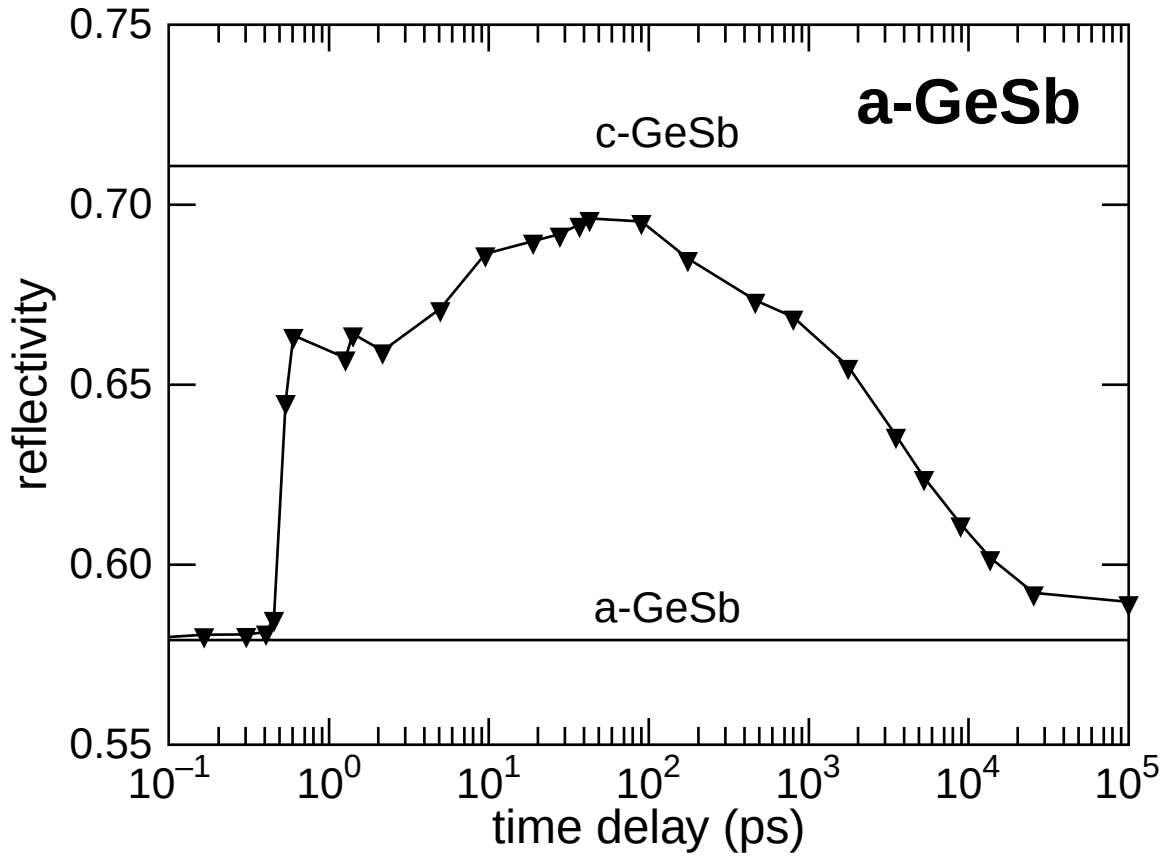

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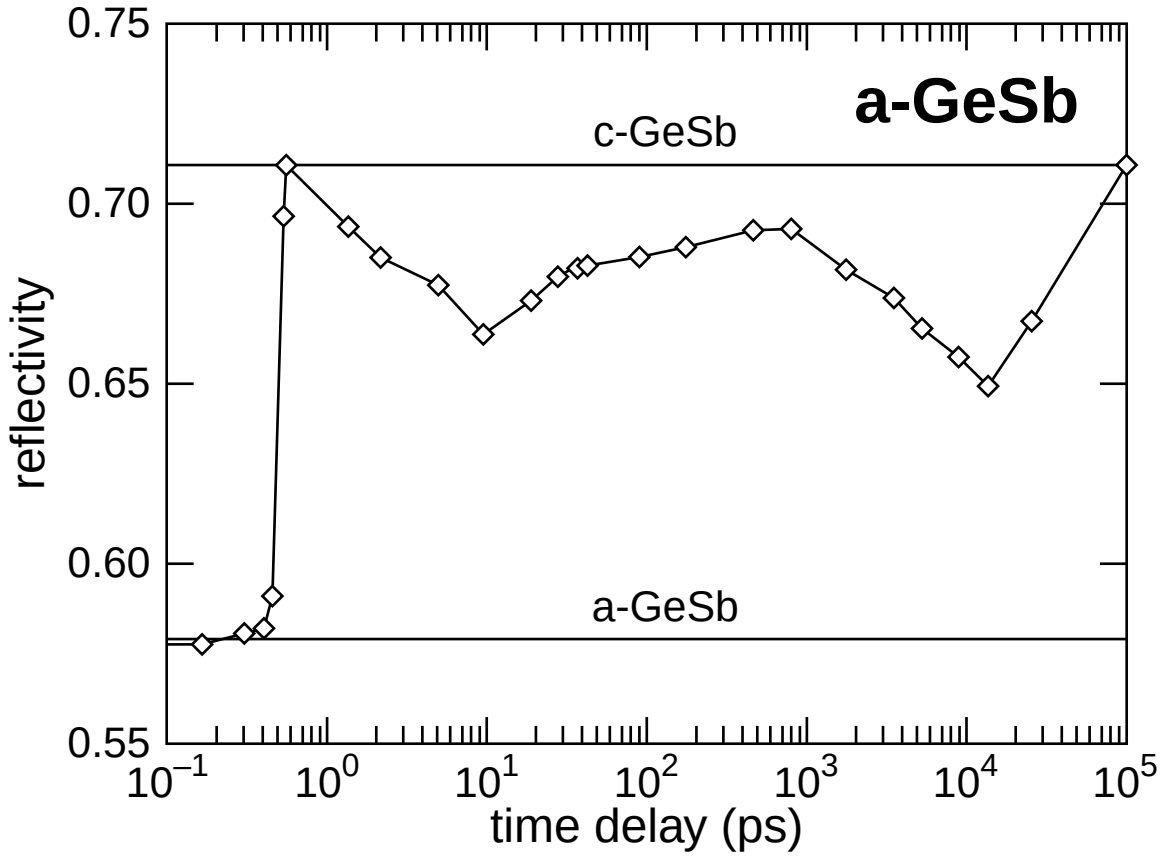

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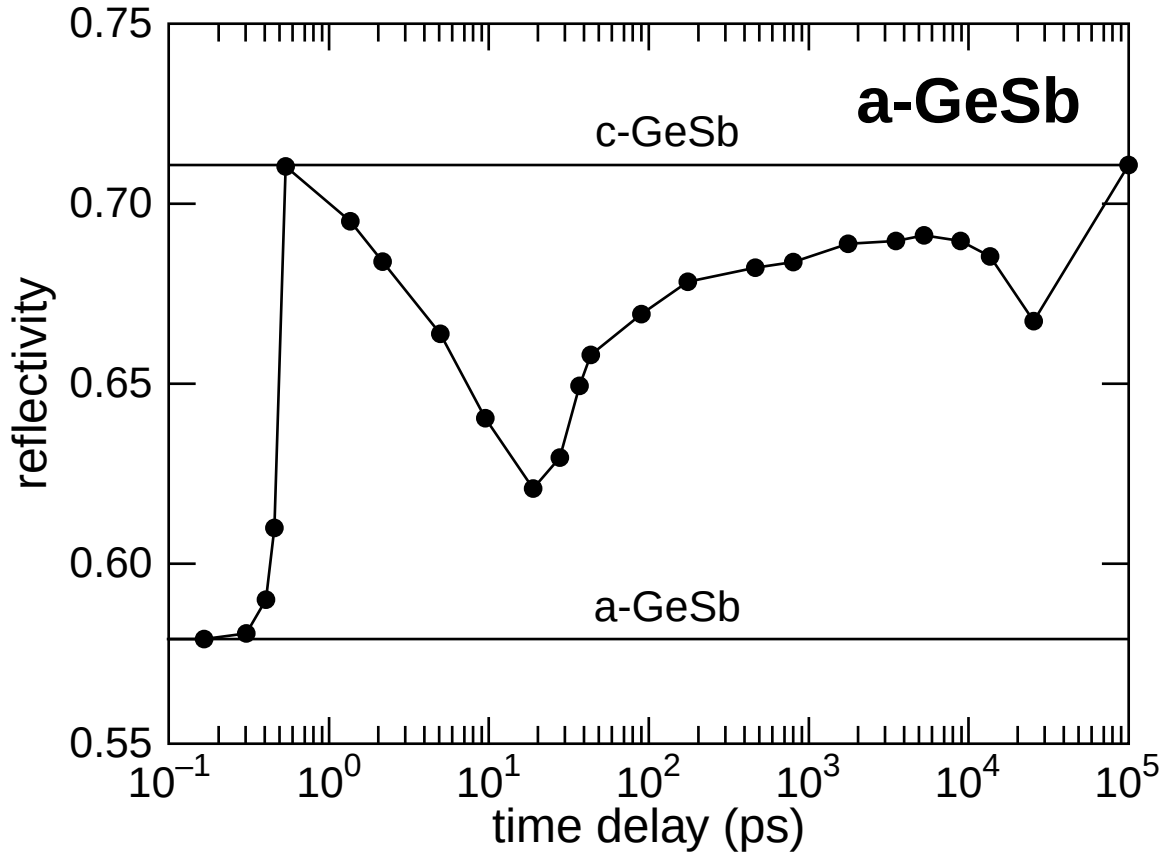
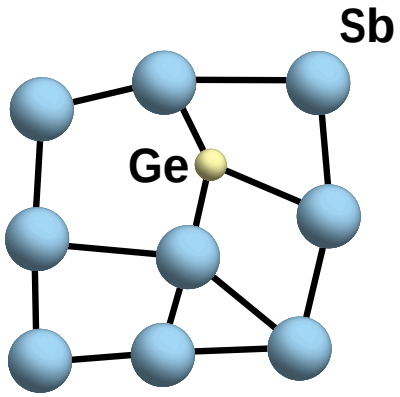


***Phys. Rev. Lett.* 81, 3679 (1998)**

Introduction

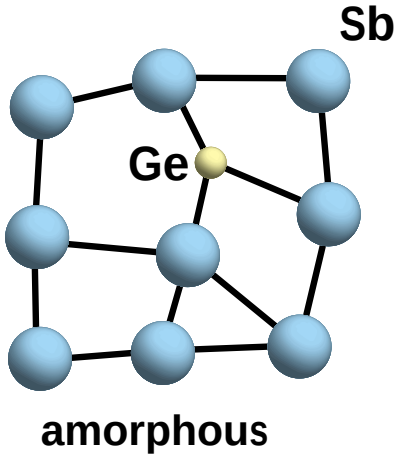
structure



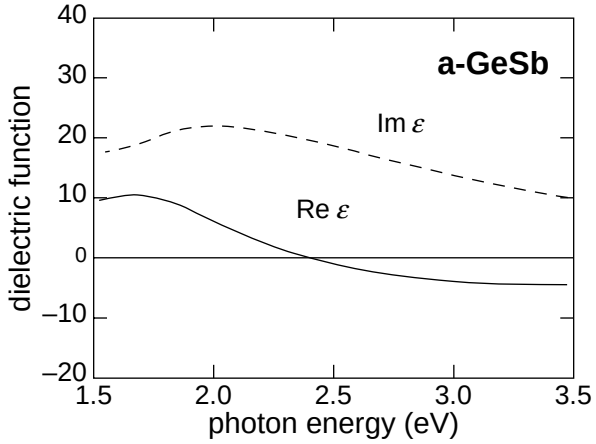
amorphous

Introduction

structure



dielectric function



Introduction

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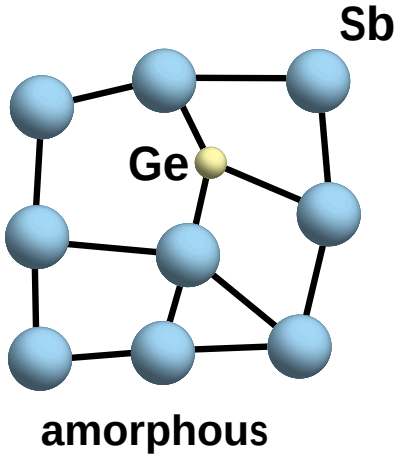
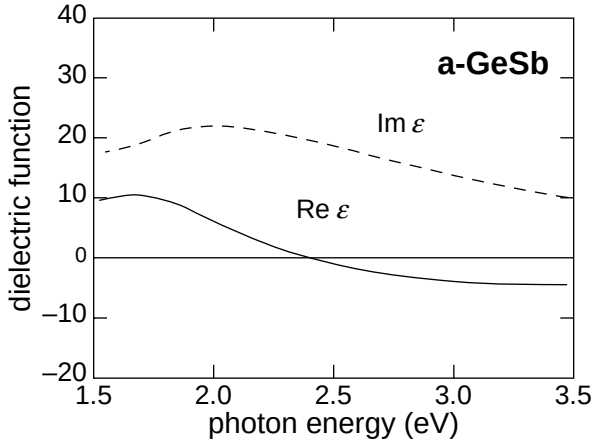
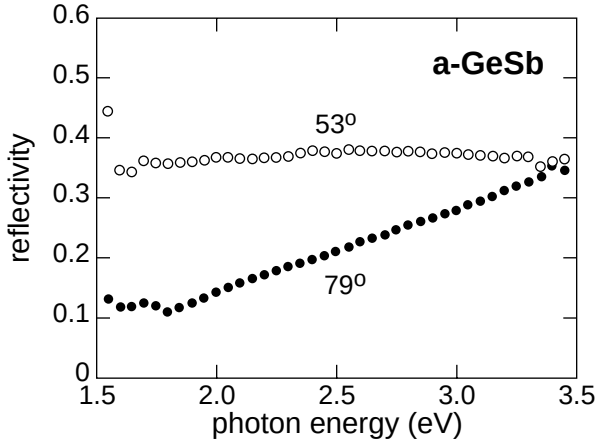


dielectric function



reflectivity



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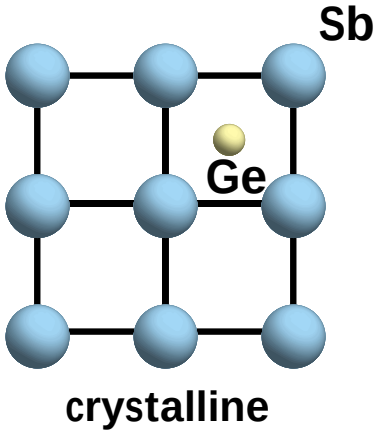
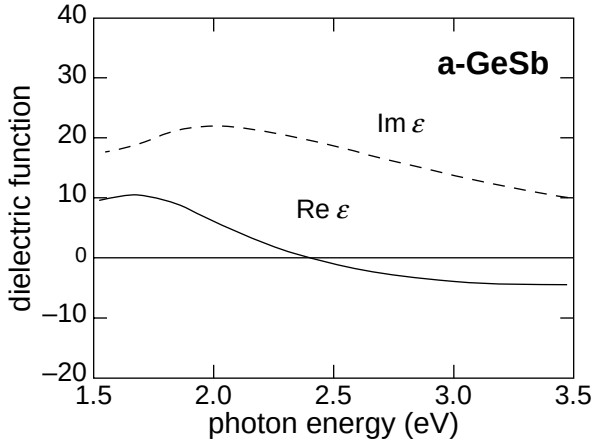
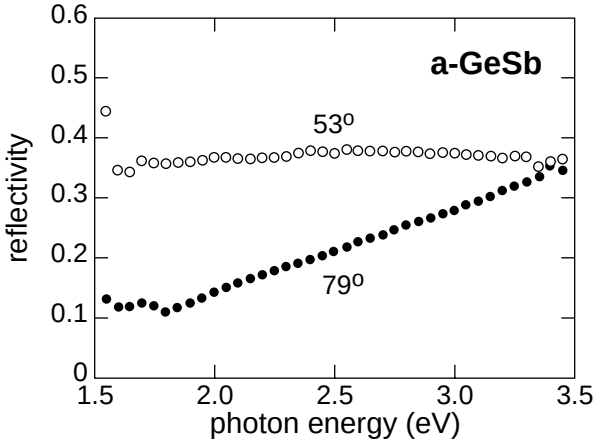


dielectric function

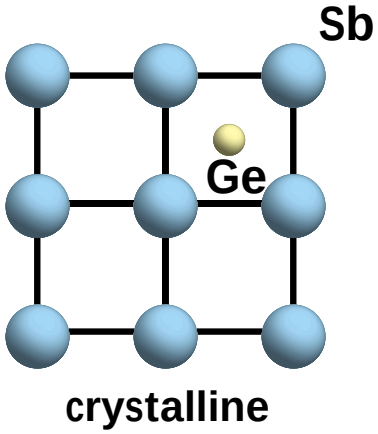


reflectivity

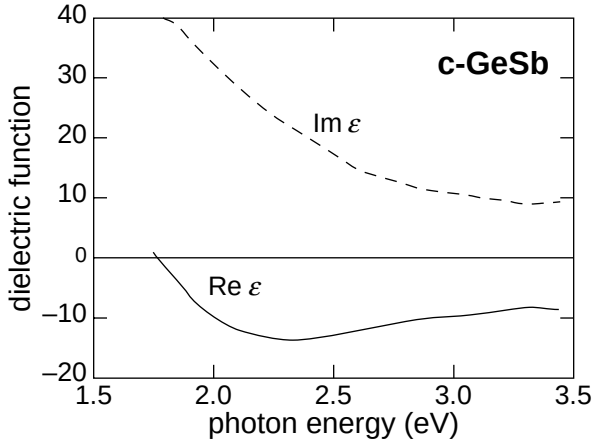


Introduction

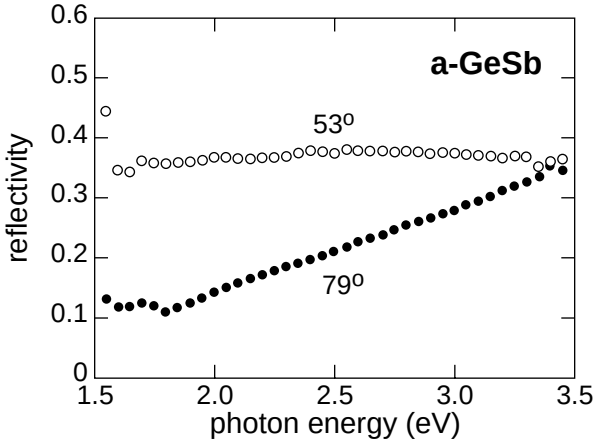
structure



dielectric function

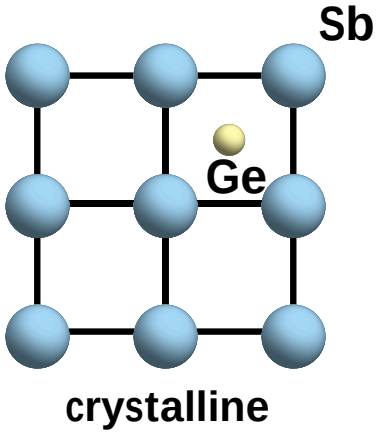


reflectivity



Introduction

structure



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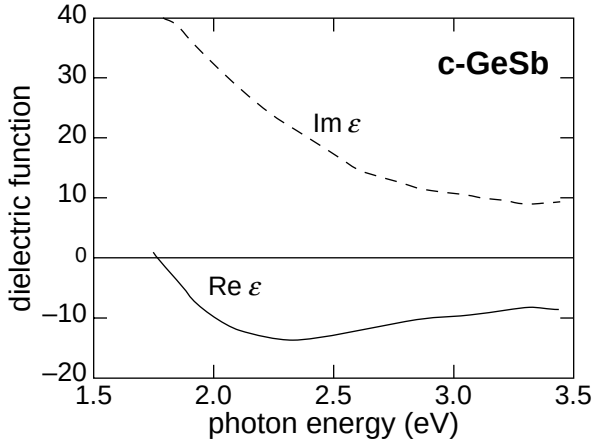
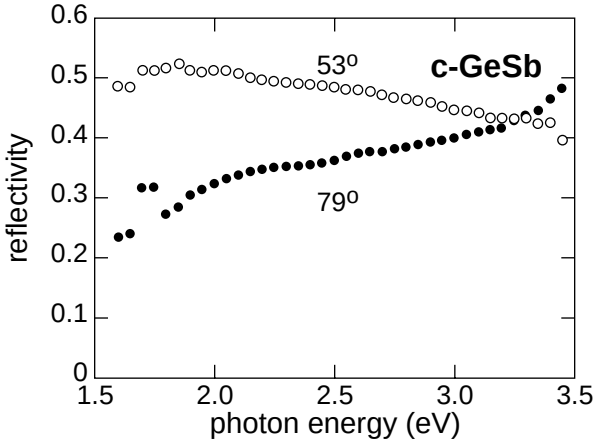


reflectivity



Introduction

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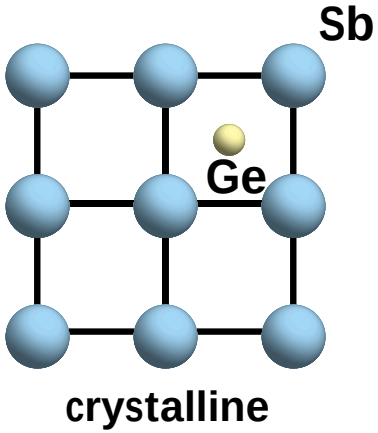

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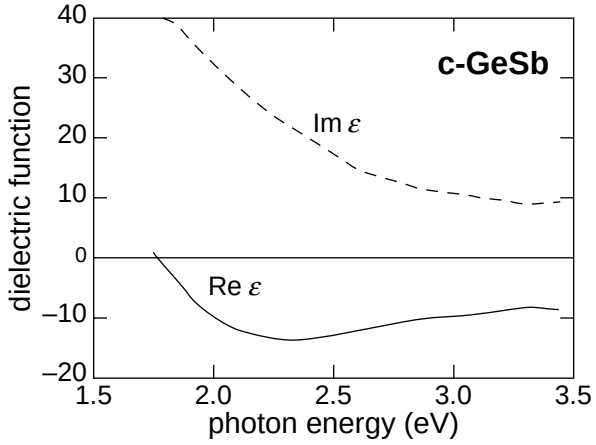

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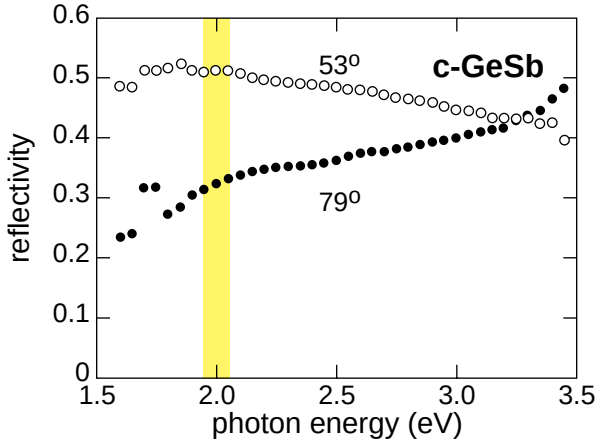
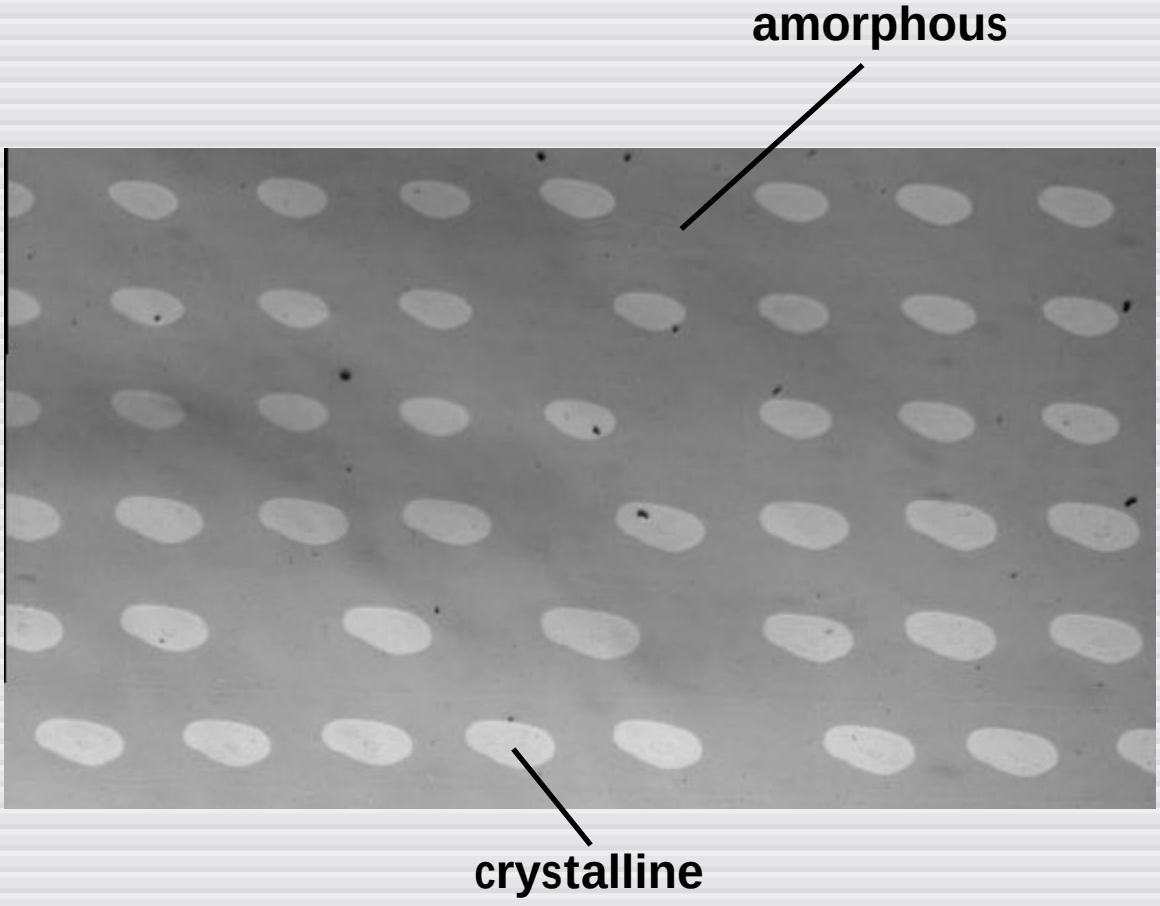


Introduction

reflectivity change



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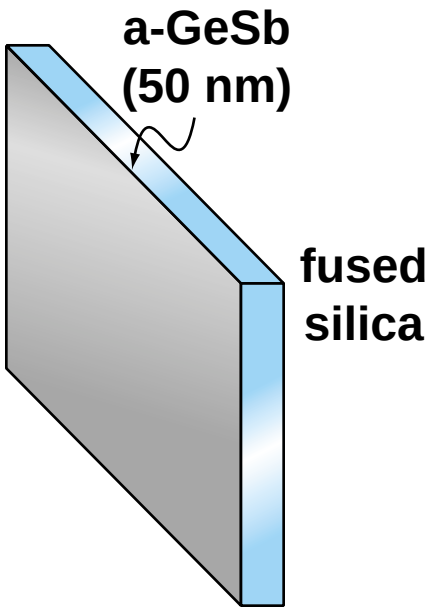

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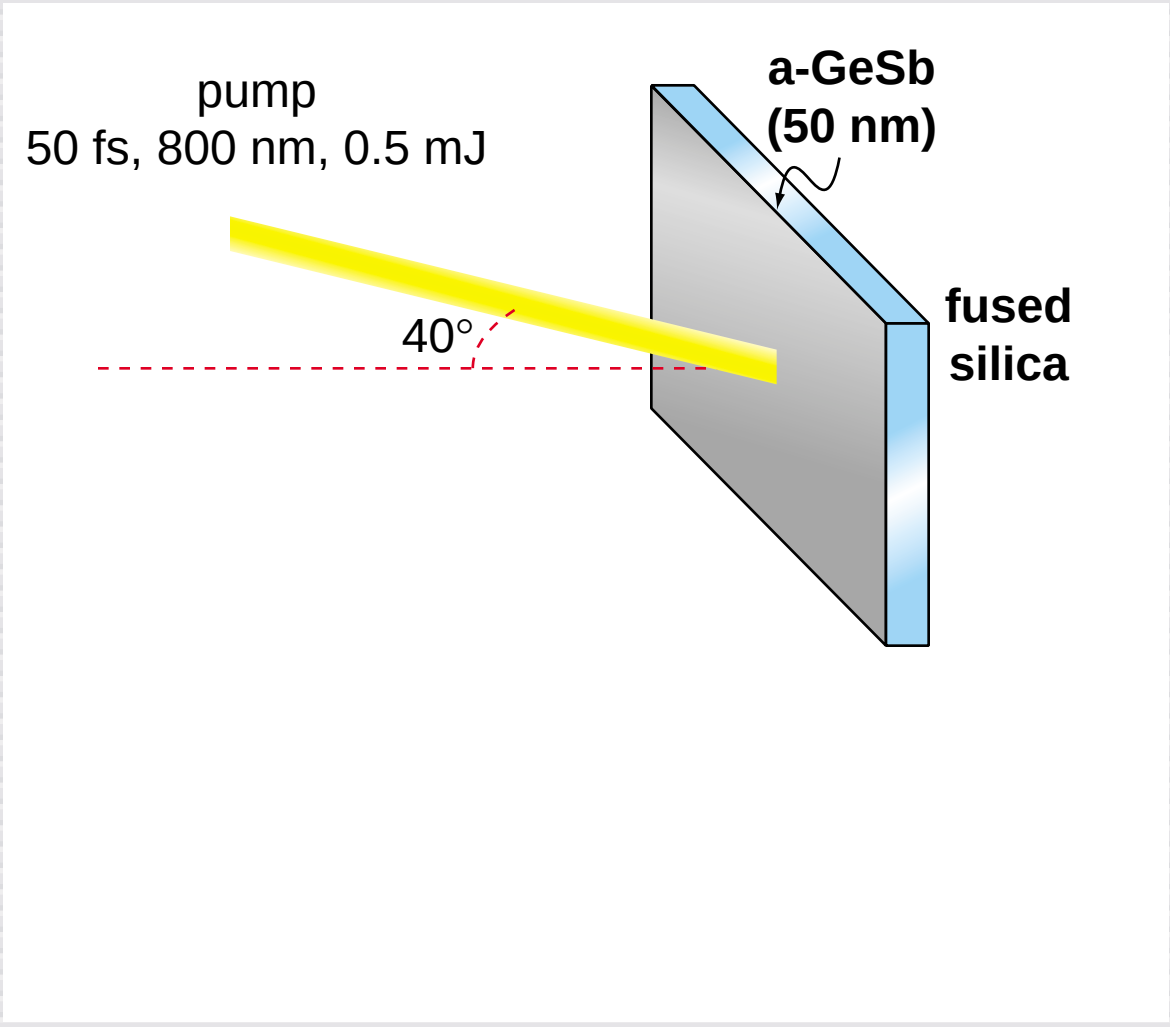

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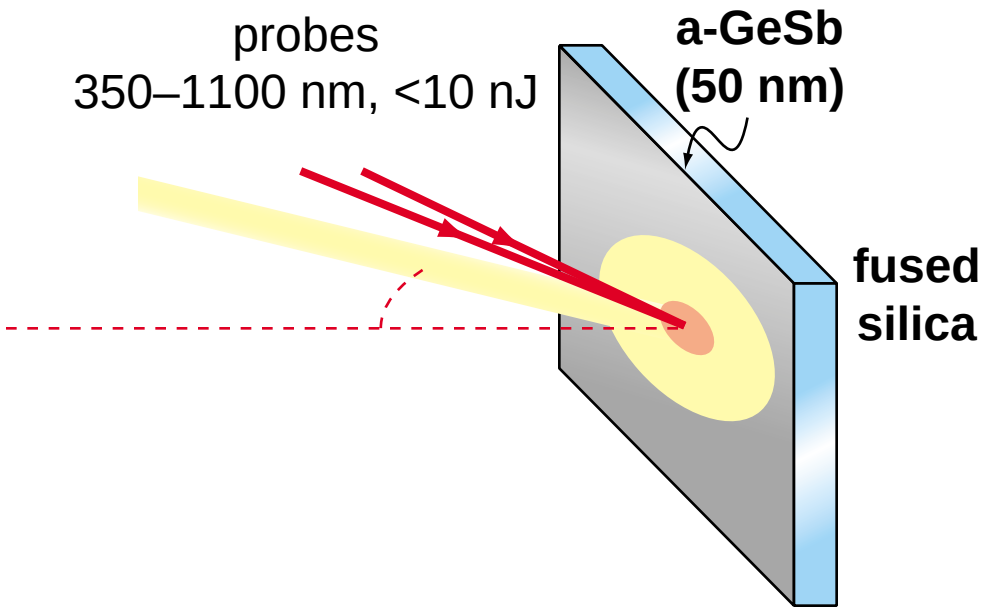

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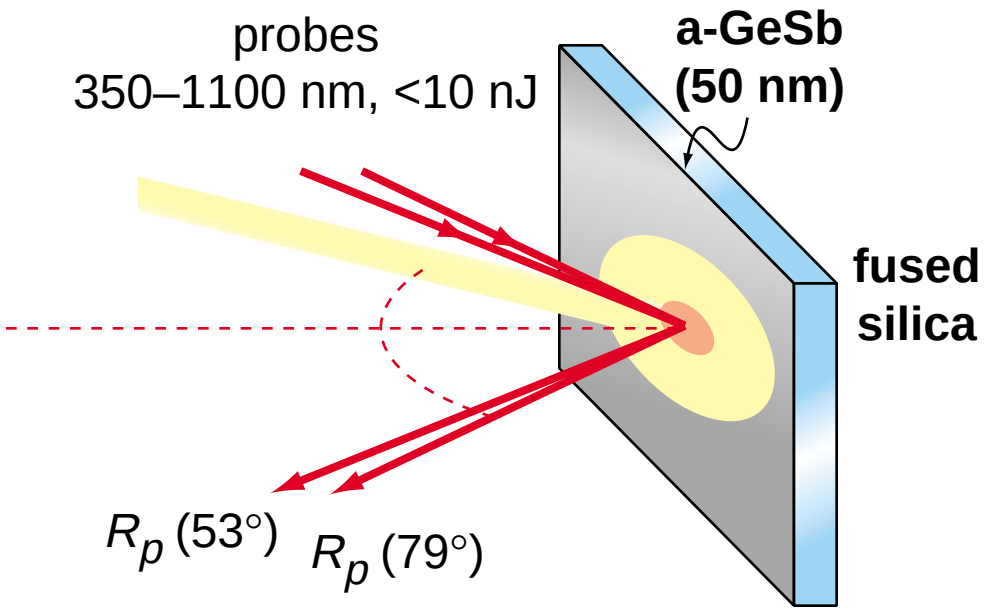

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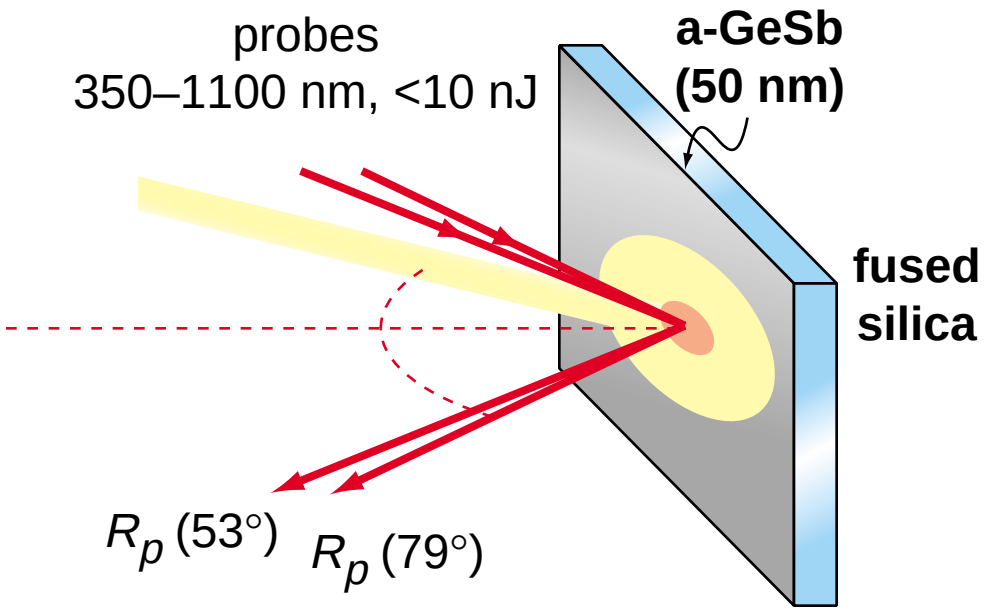
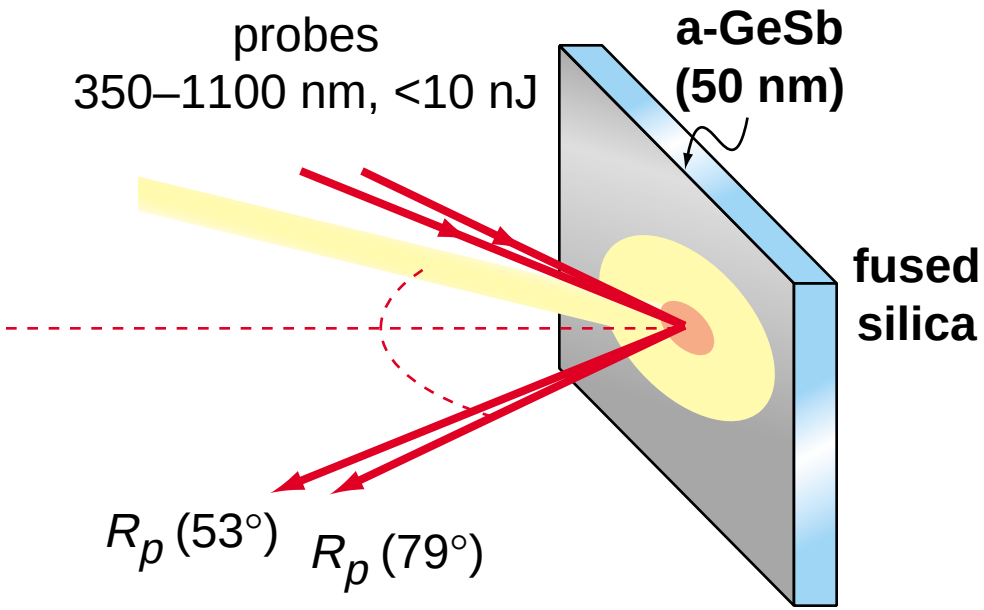


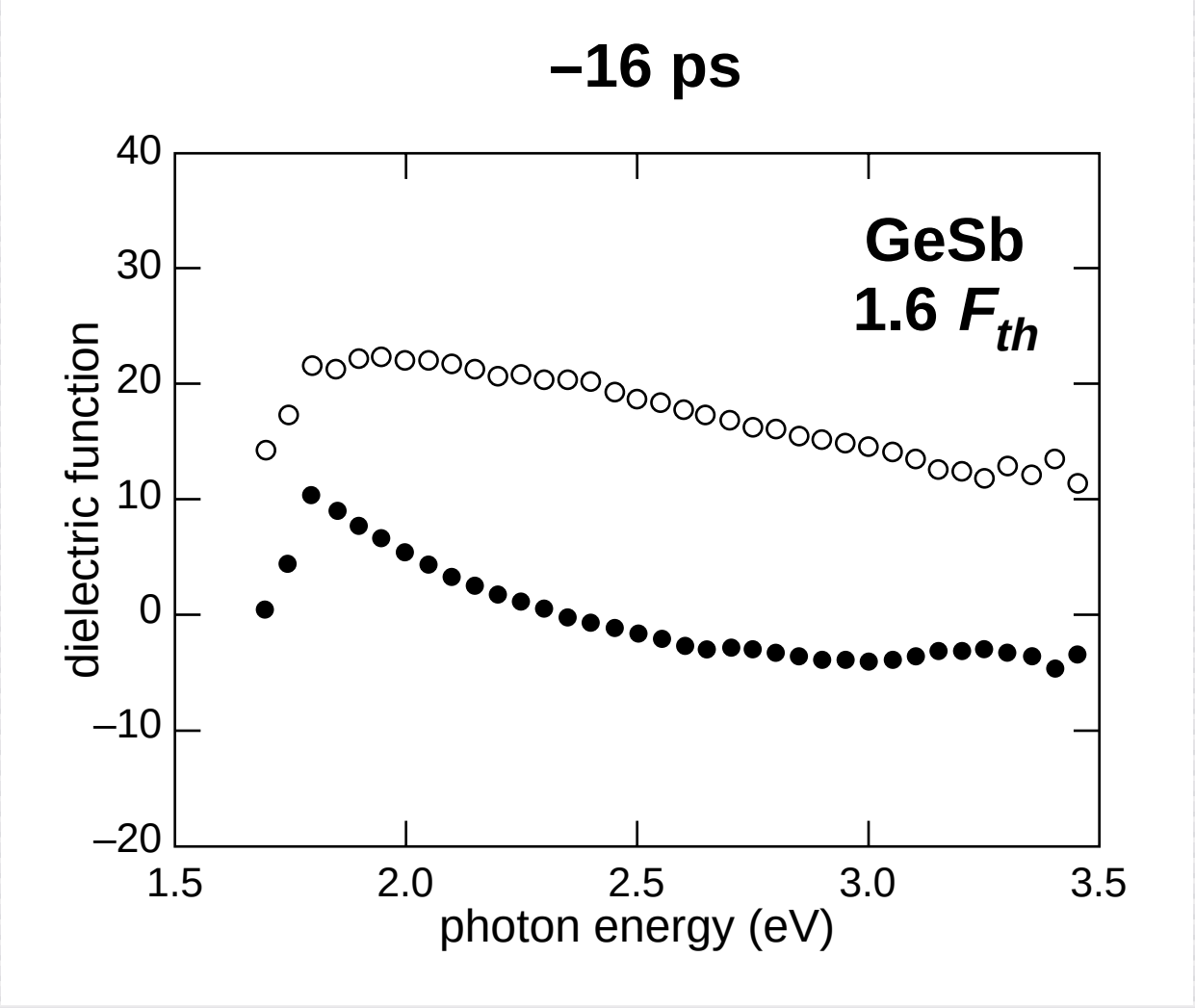
Fresnel
equations

Method

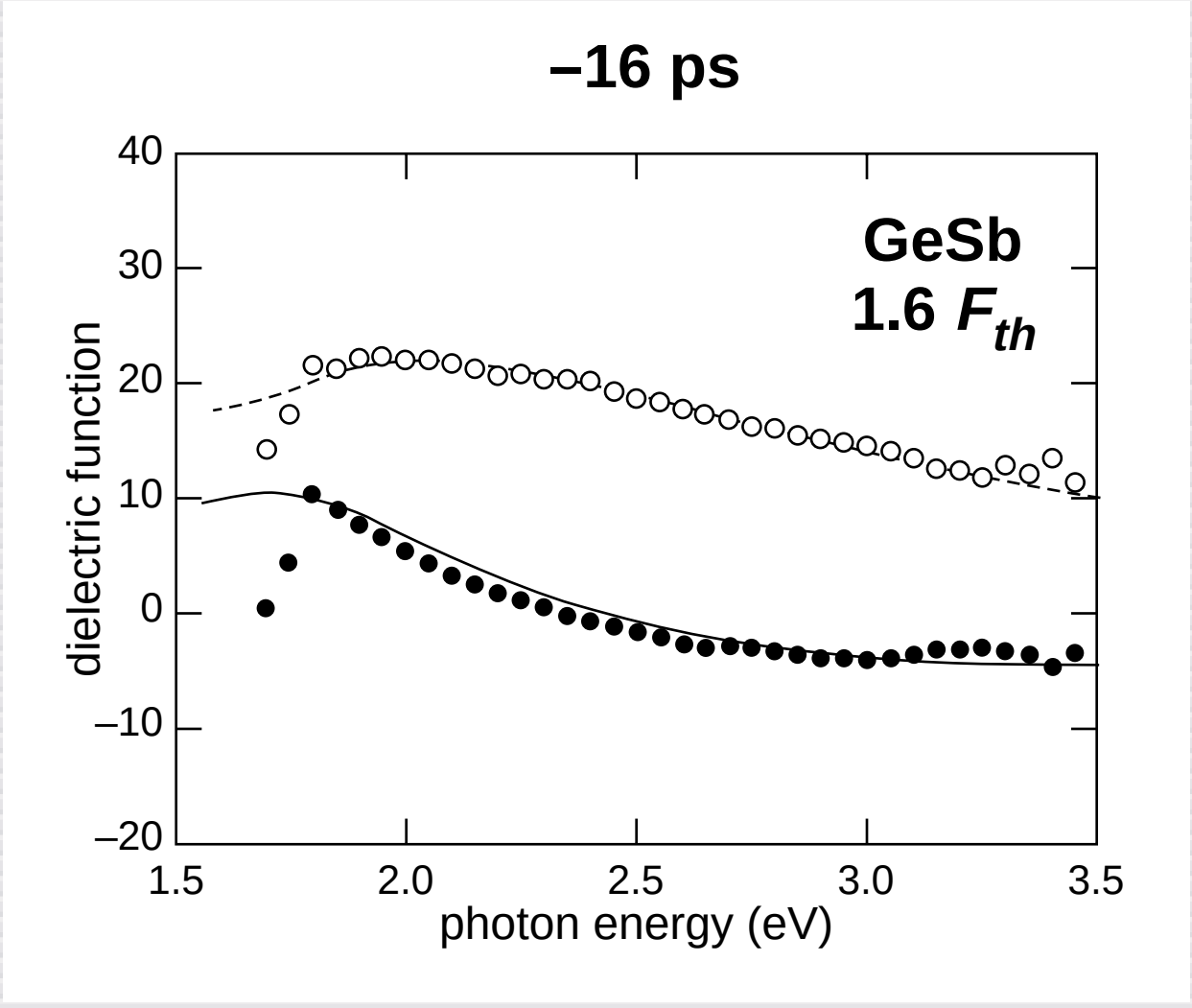


Fresnel equations → Re ε(ω), Im ε(ω)

Results


–16 ps
GeSb
1.6 F_{th}
dielectric function
photon energy (eV)
40
30
20
10
0
–10
–20
1.5
2.0
2.5
3.0
3.5

Results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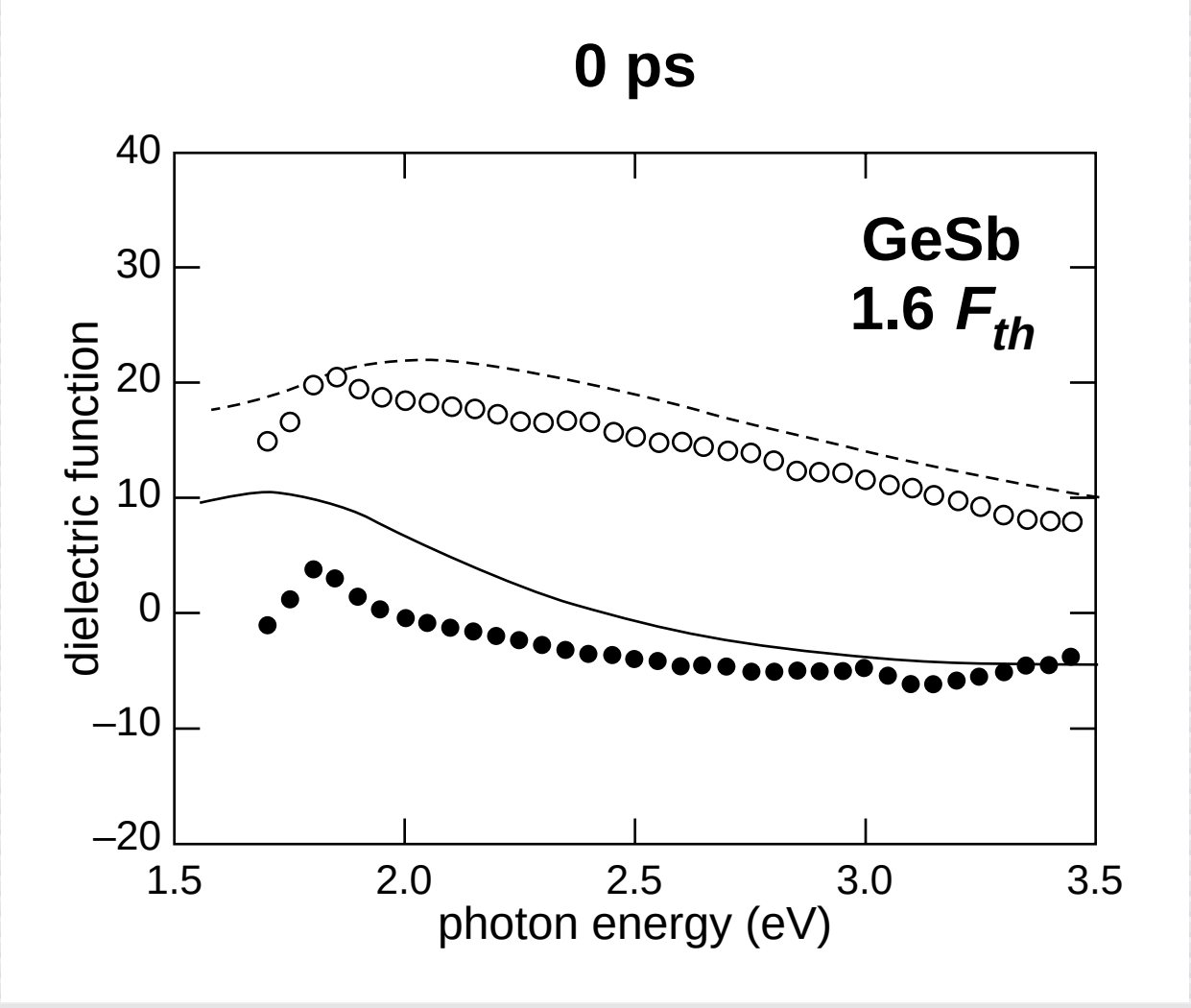
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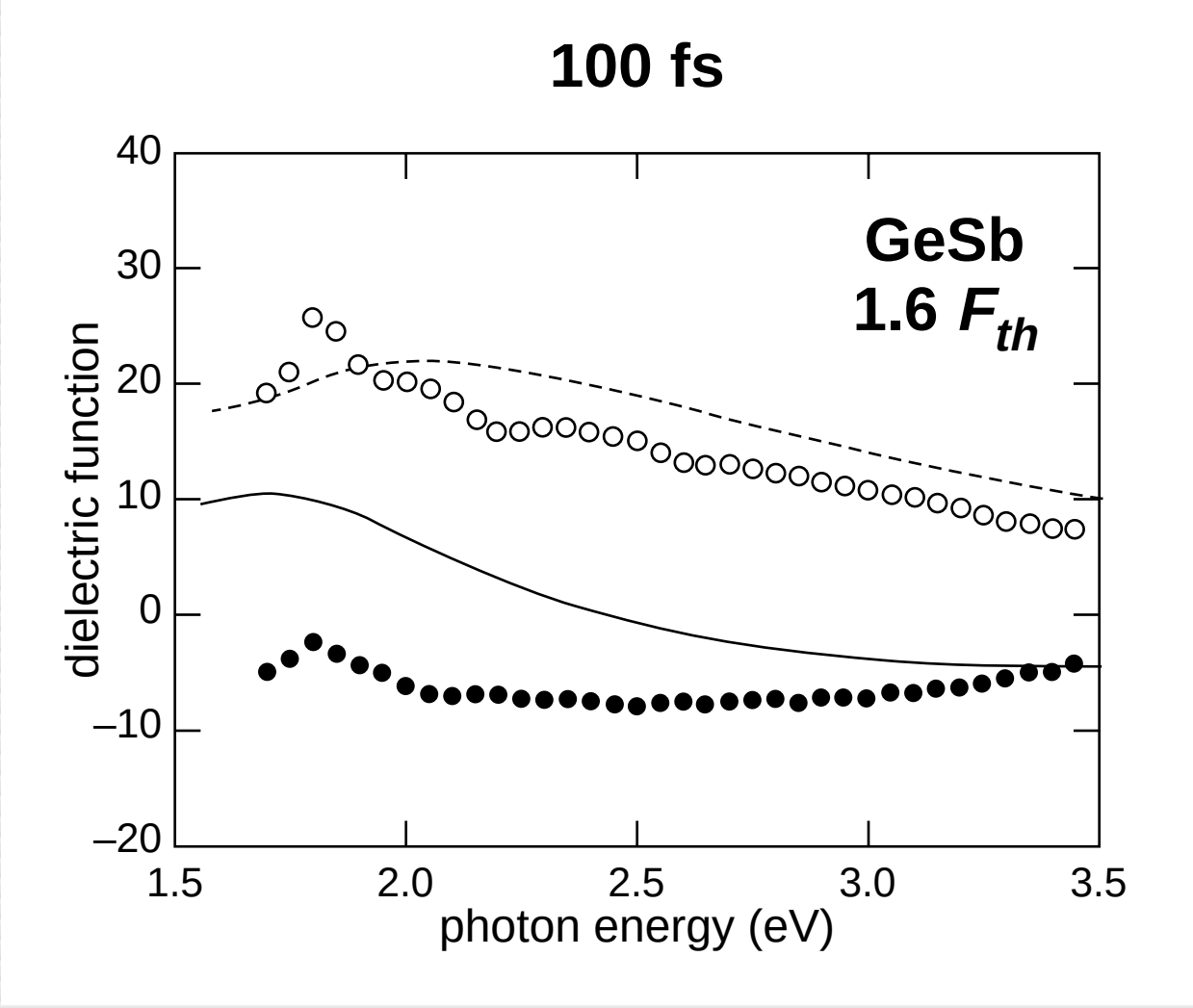
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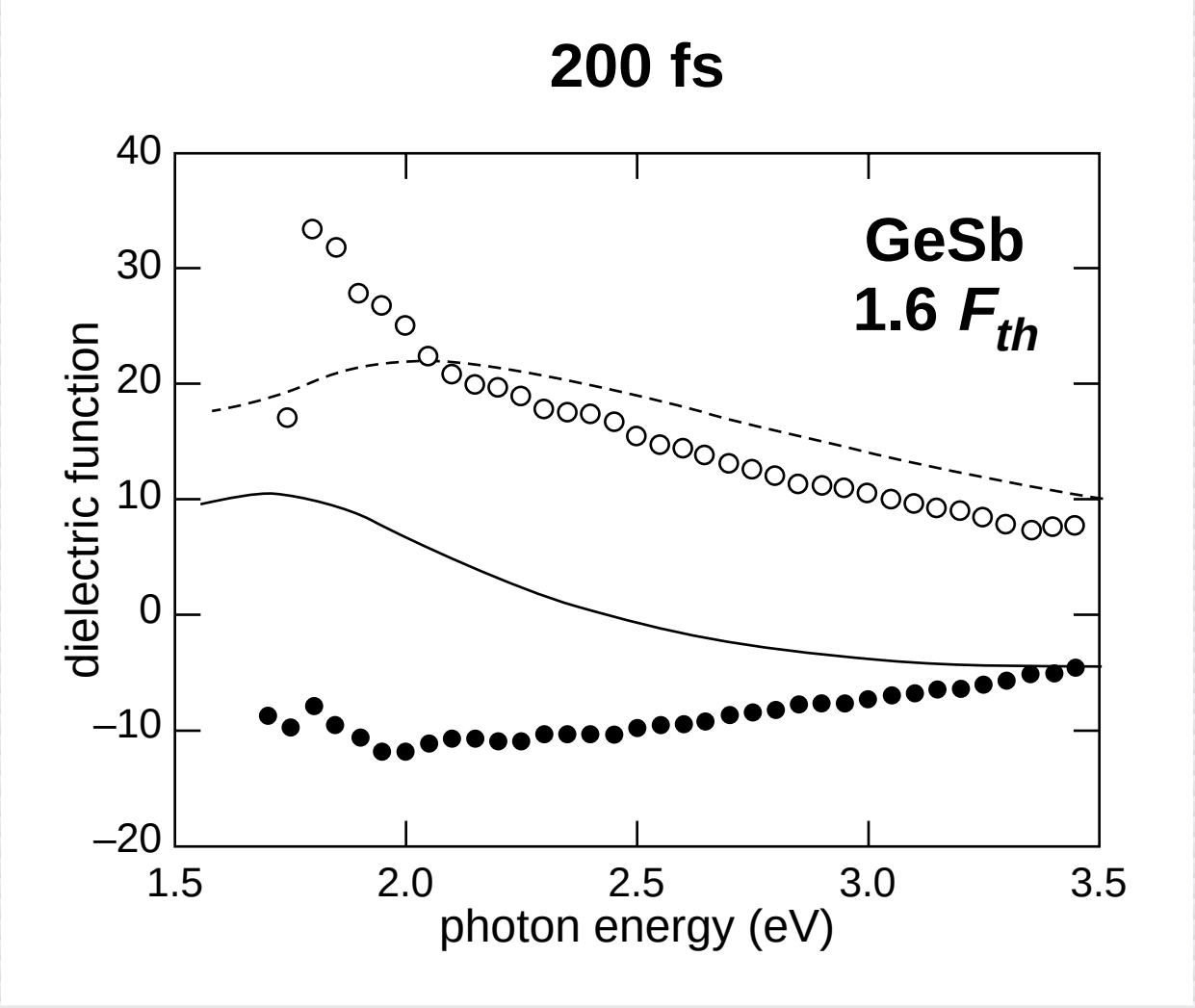
Results


200 fs
GeSb
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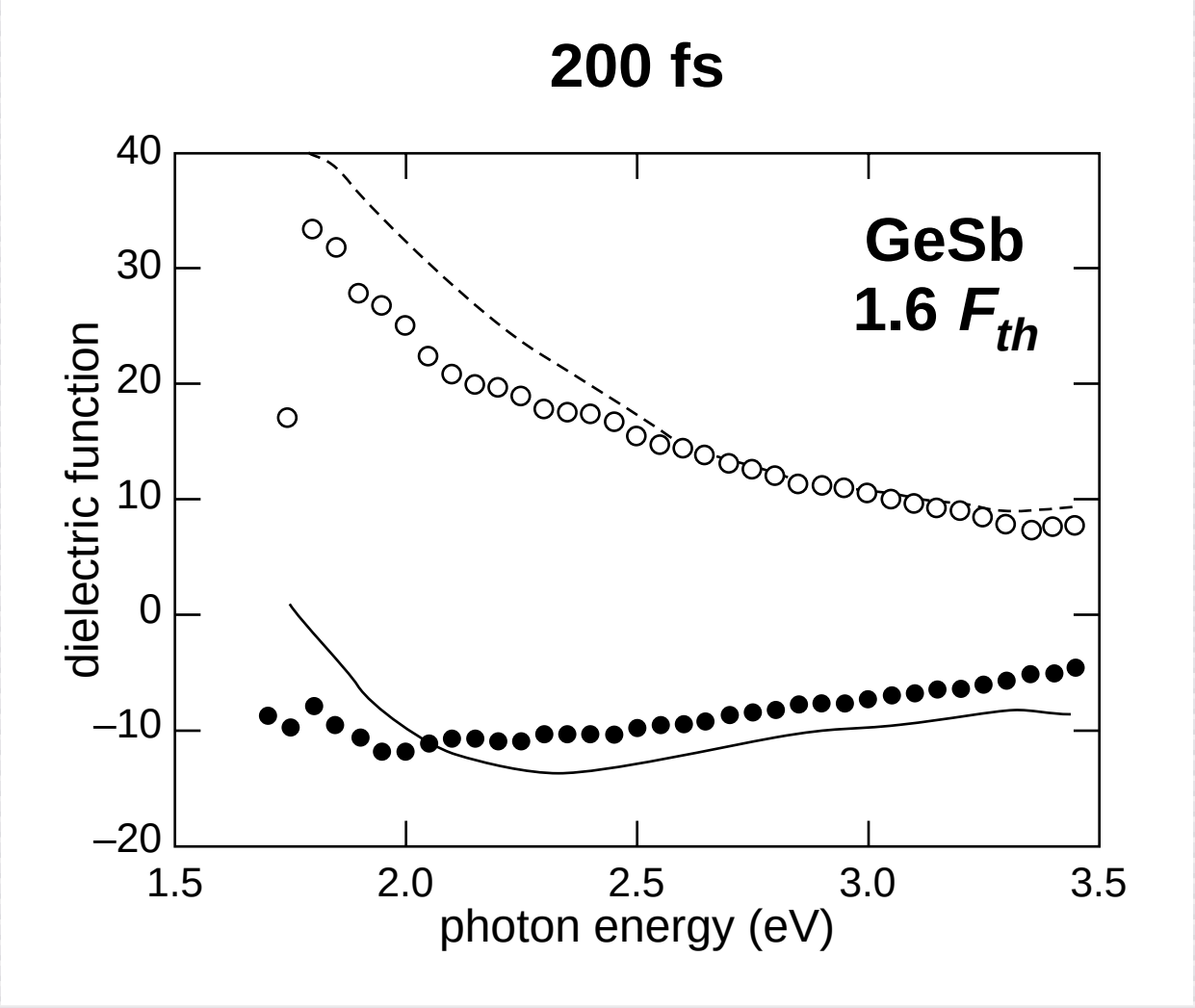
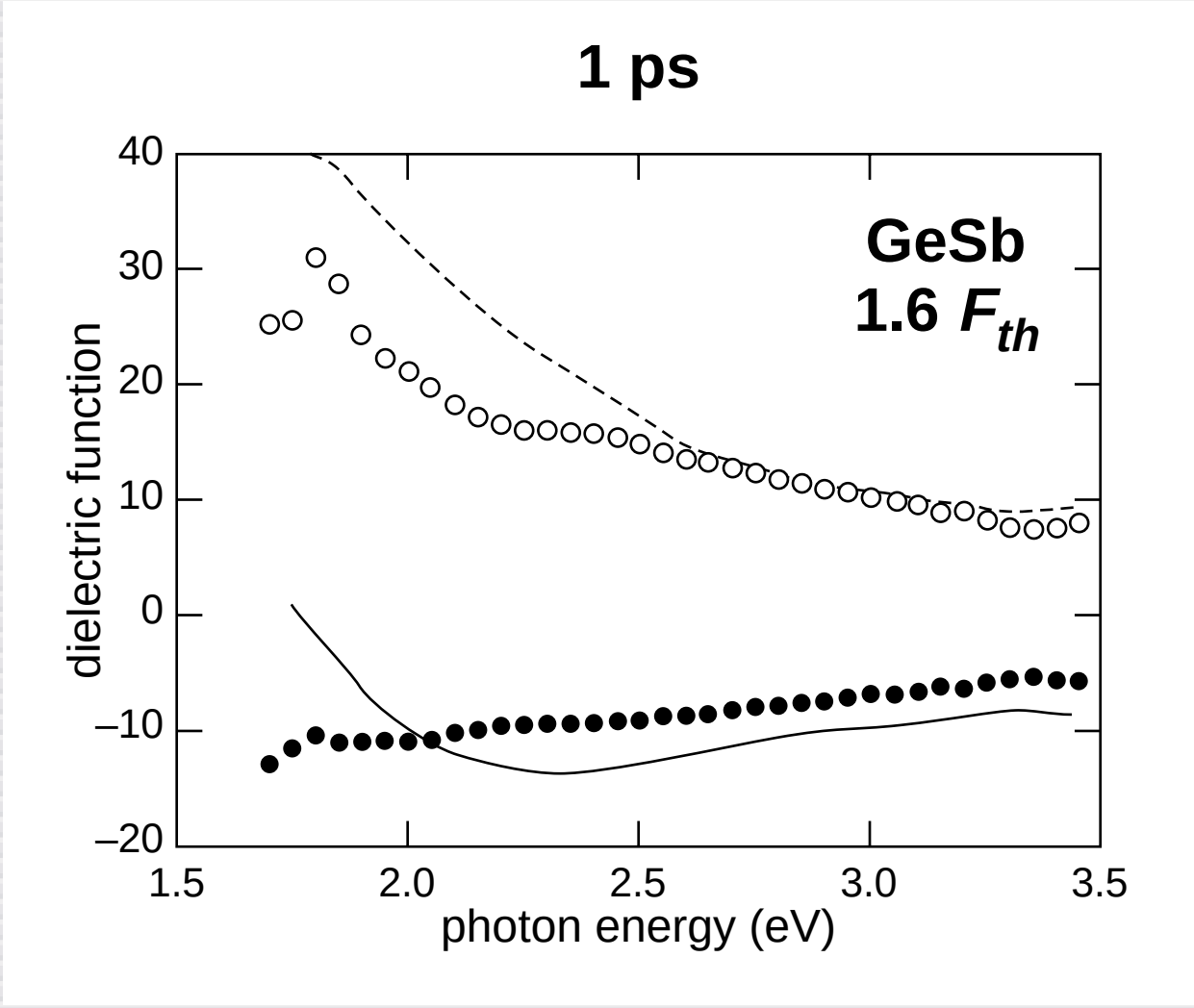
Results



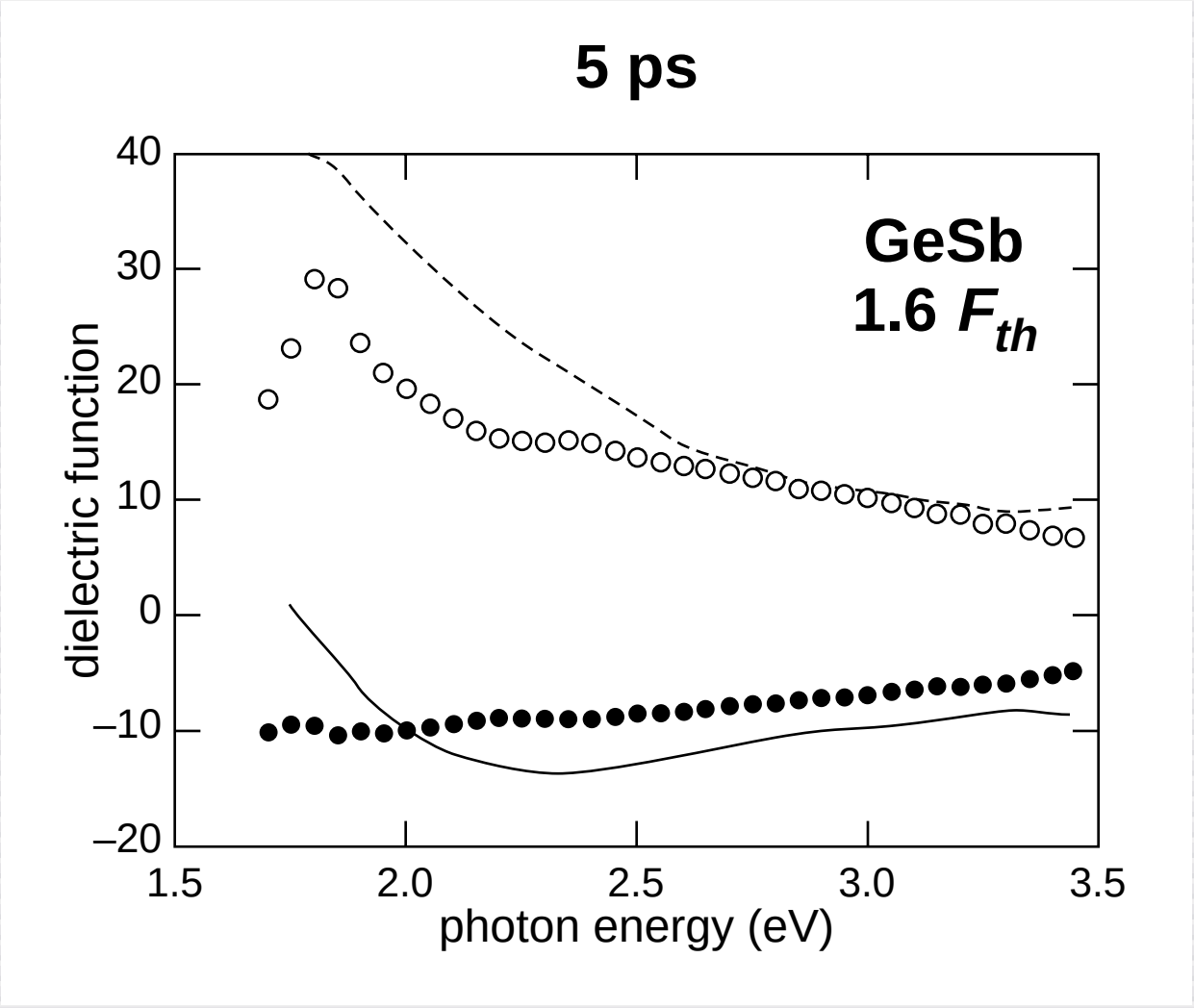
not crystalline

Results



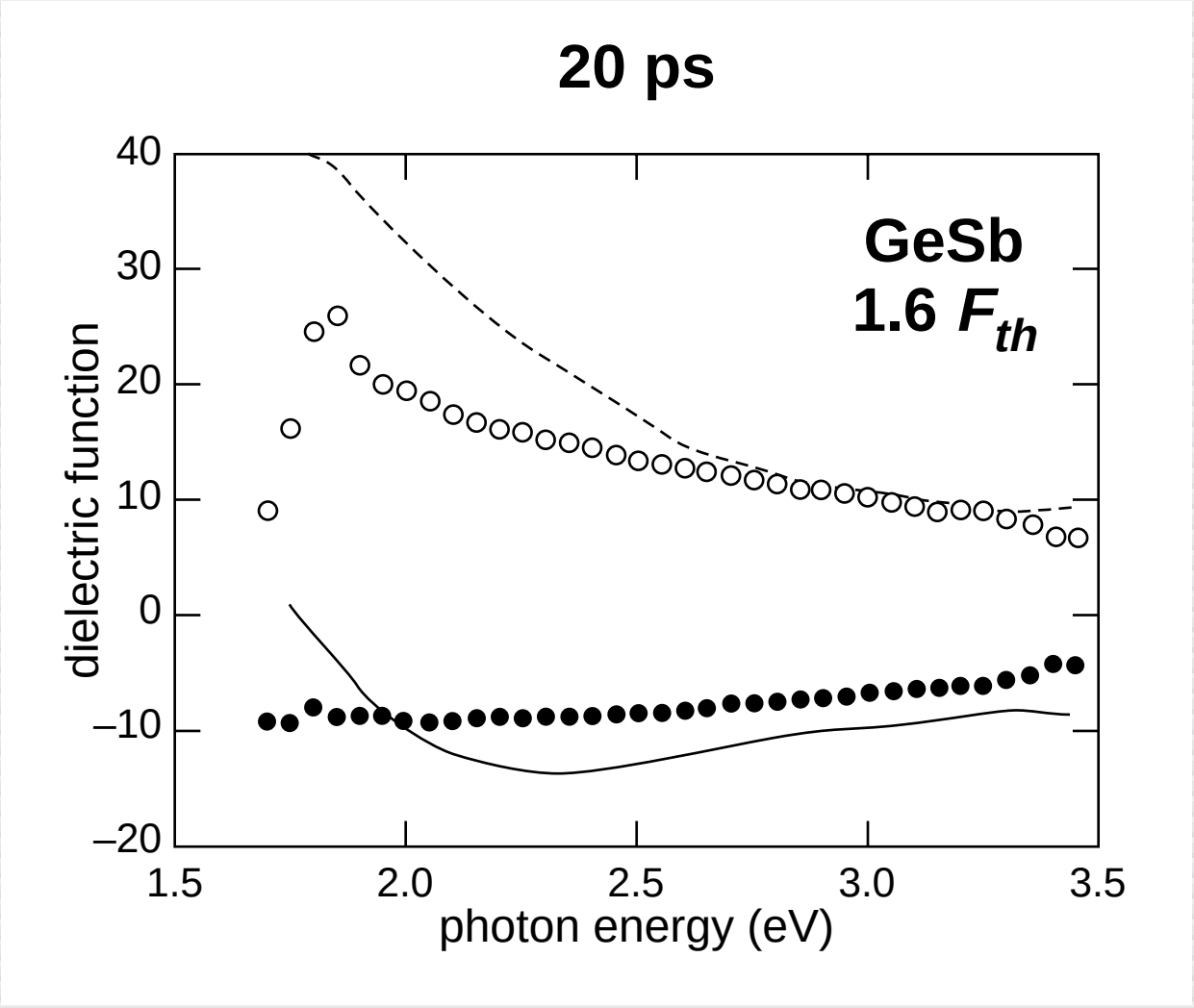
not crystalline

Results



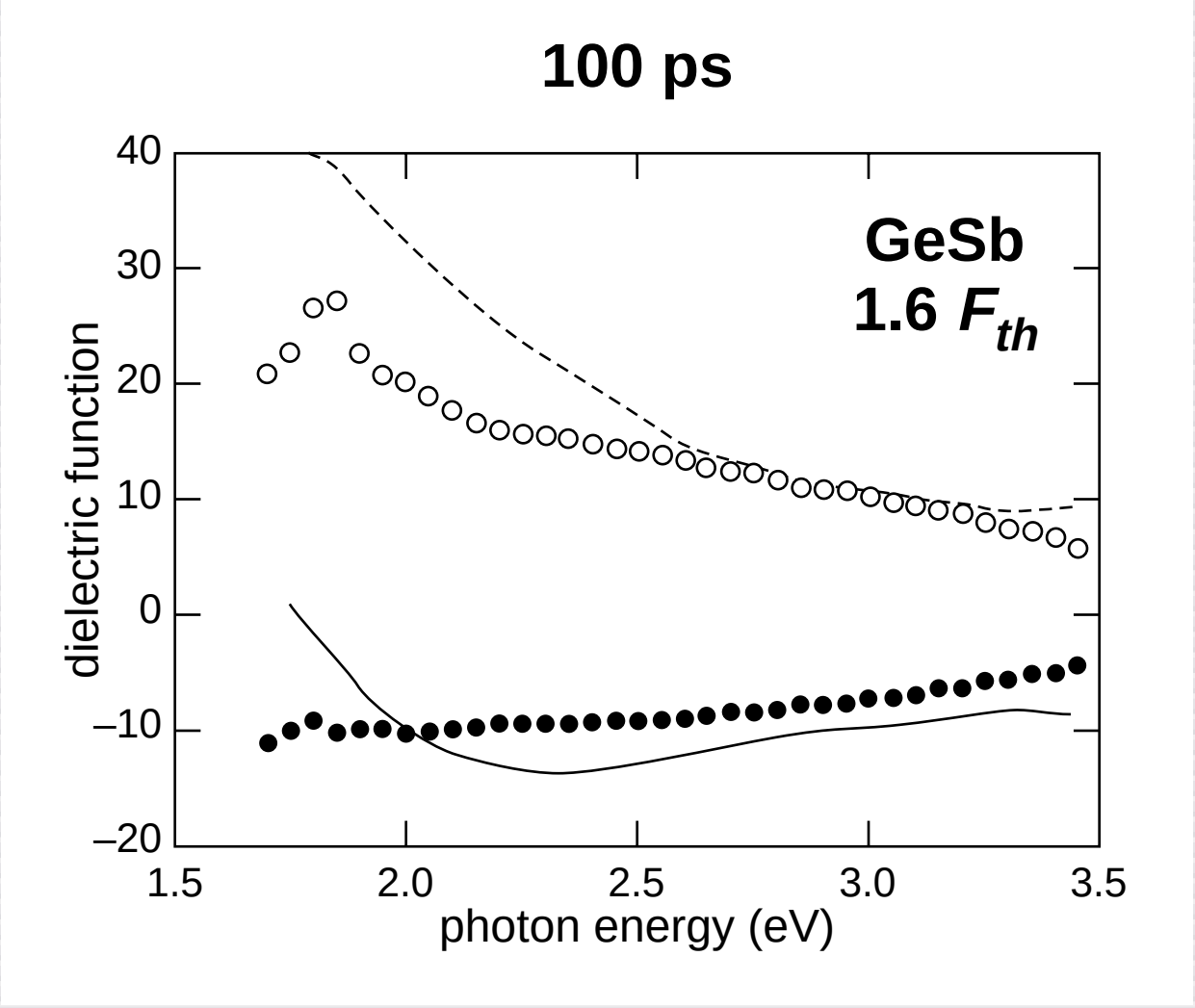
not crystalline

Results



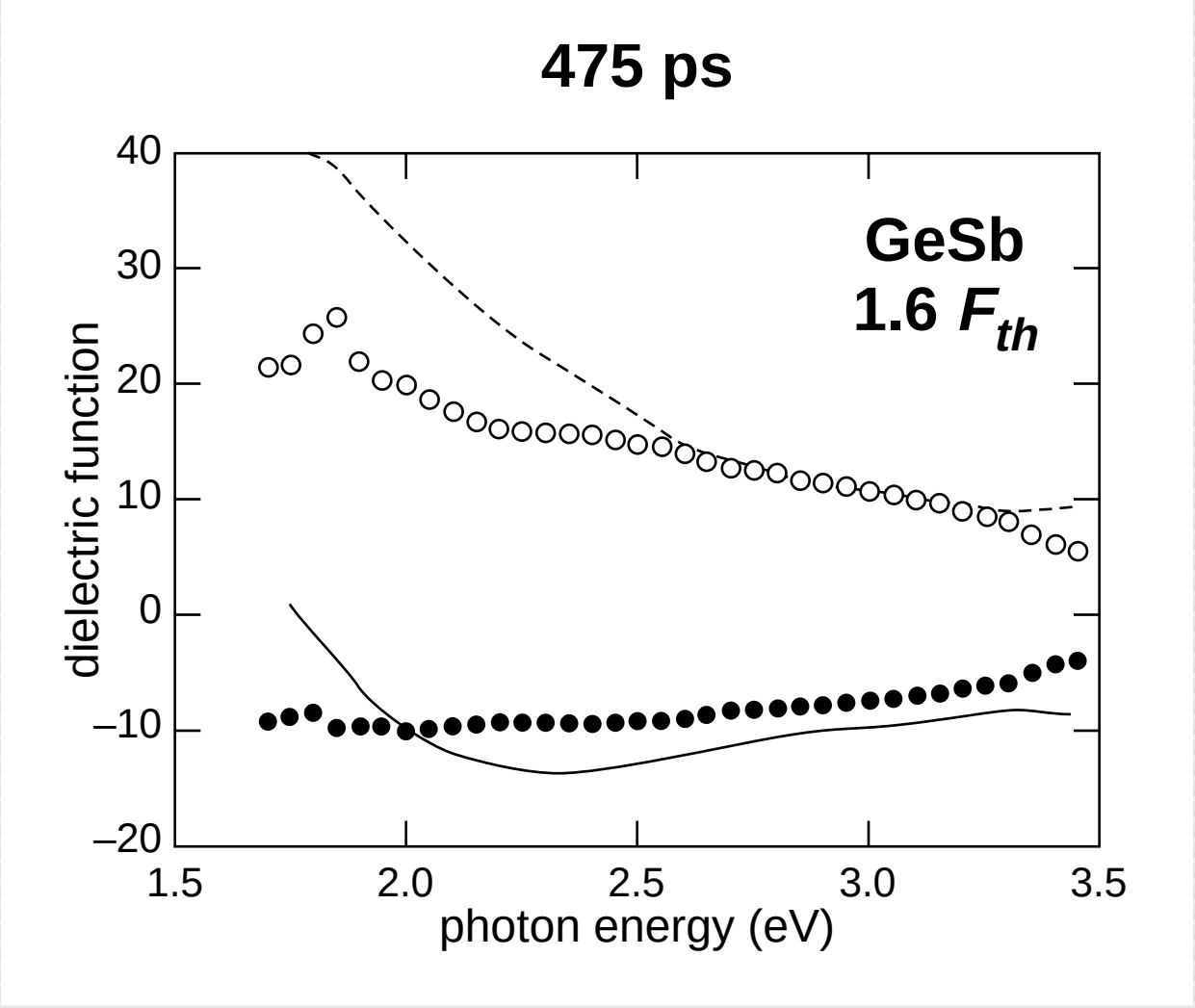
not crystalline

Results



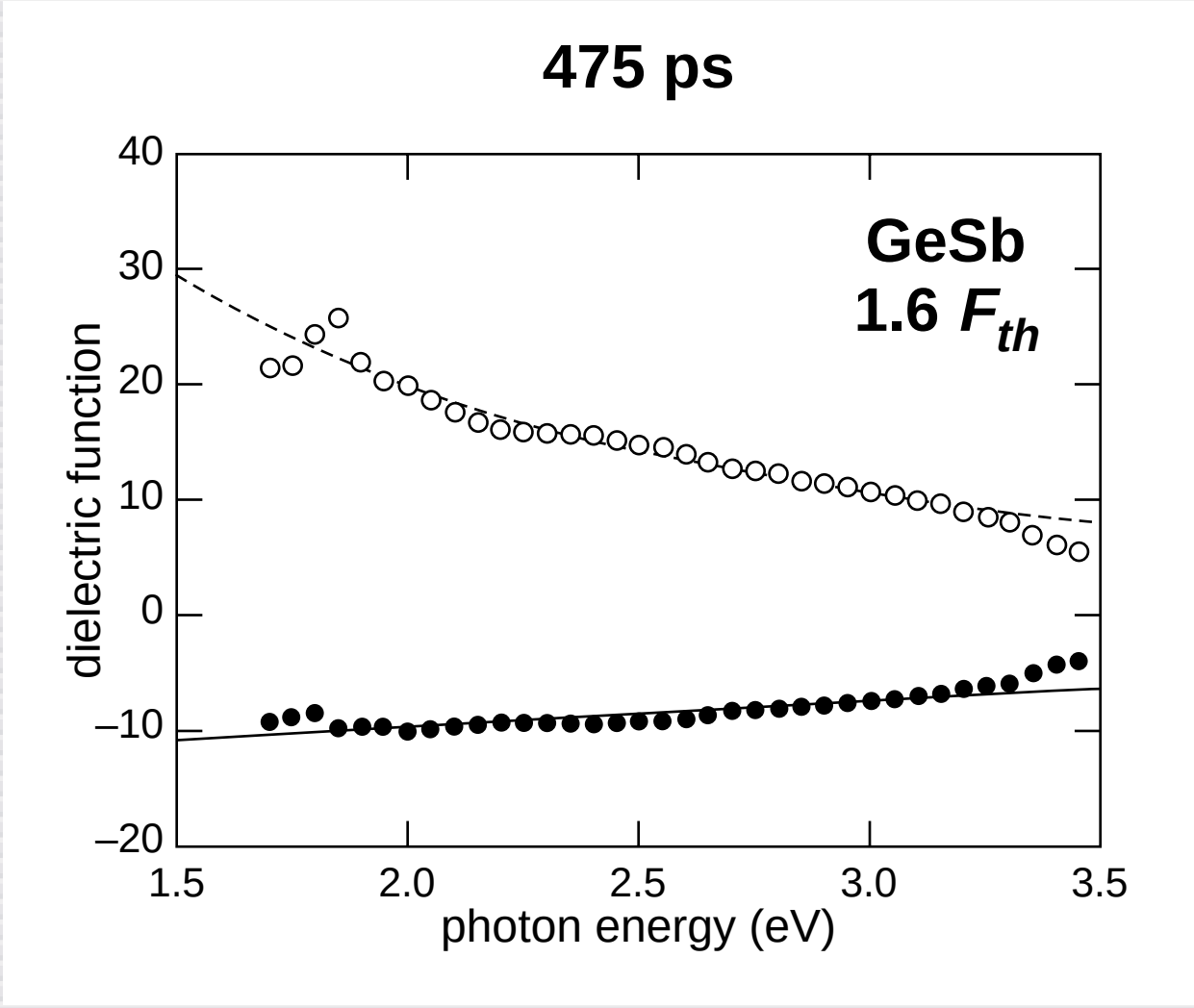
not crystalline

Results



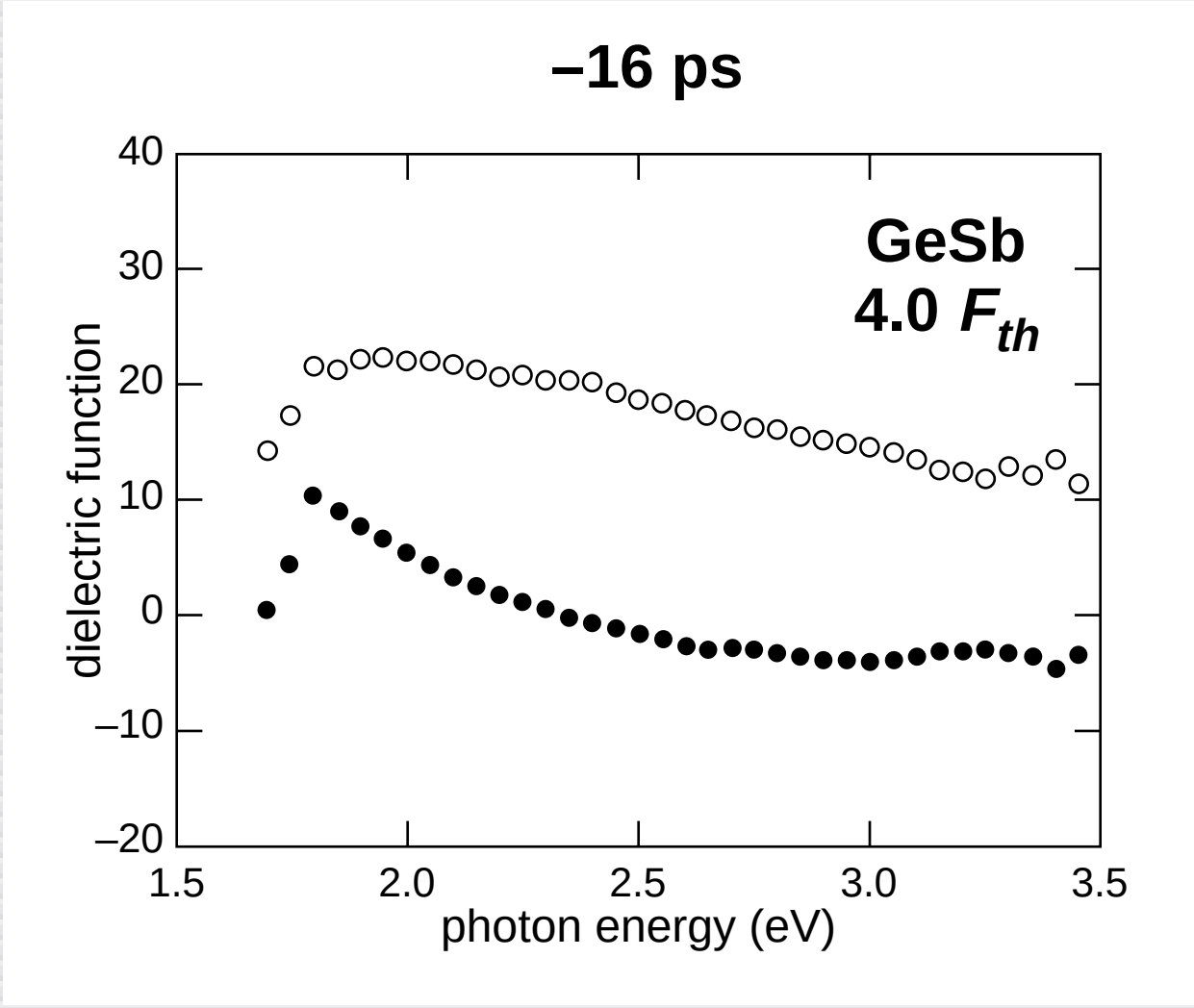
not crystalline

Results



Drude-like after 1 ps

Results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GeSb
4.0 F_{th}
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photon energy (eV)
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30
20
10
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–10
–20
1.5
2.0
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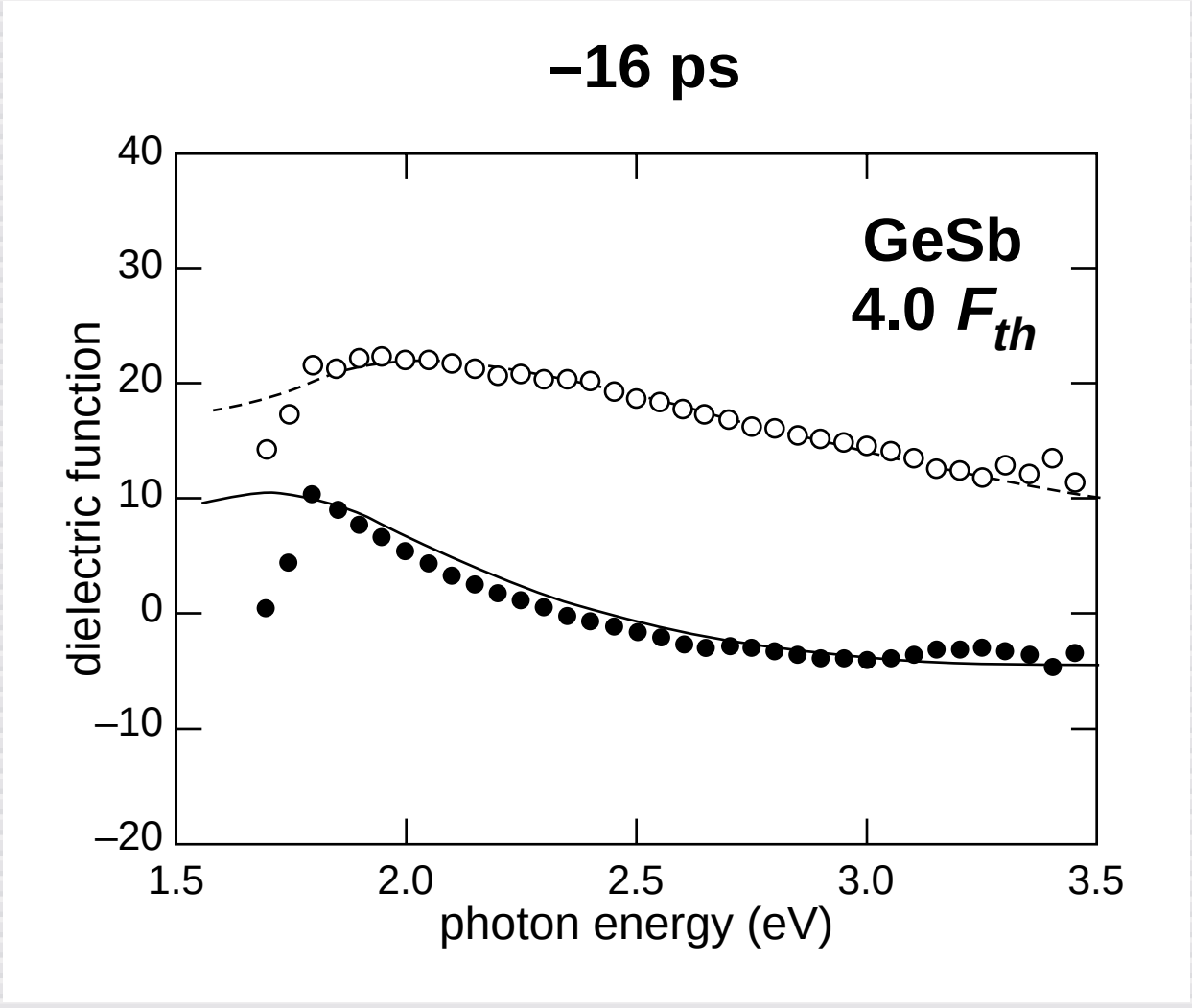
3.5

Results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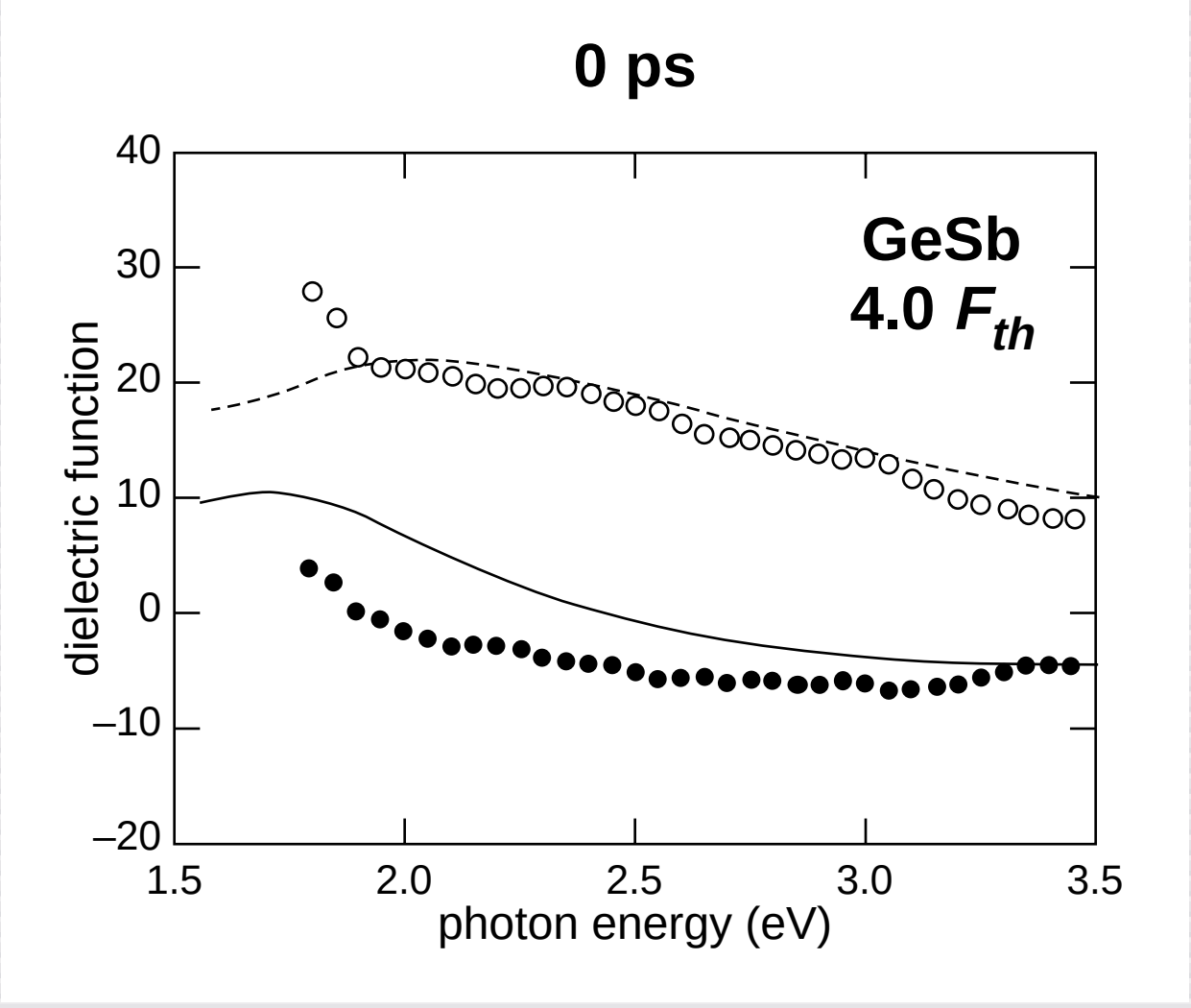
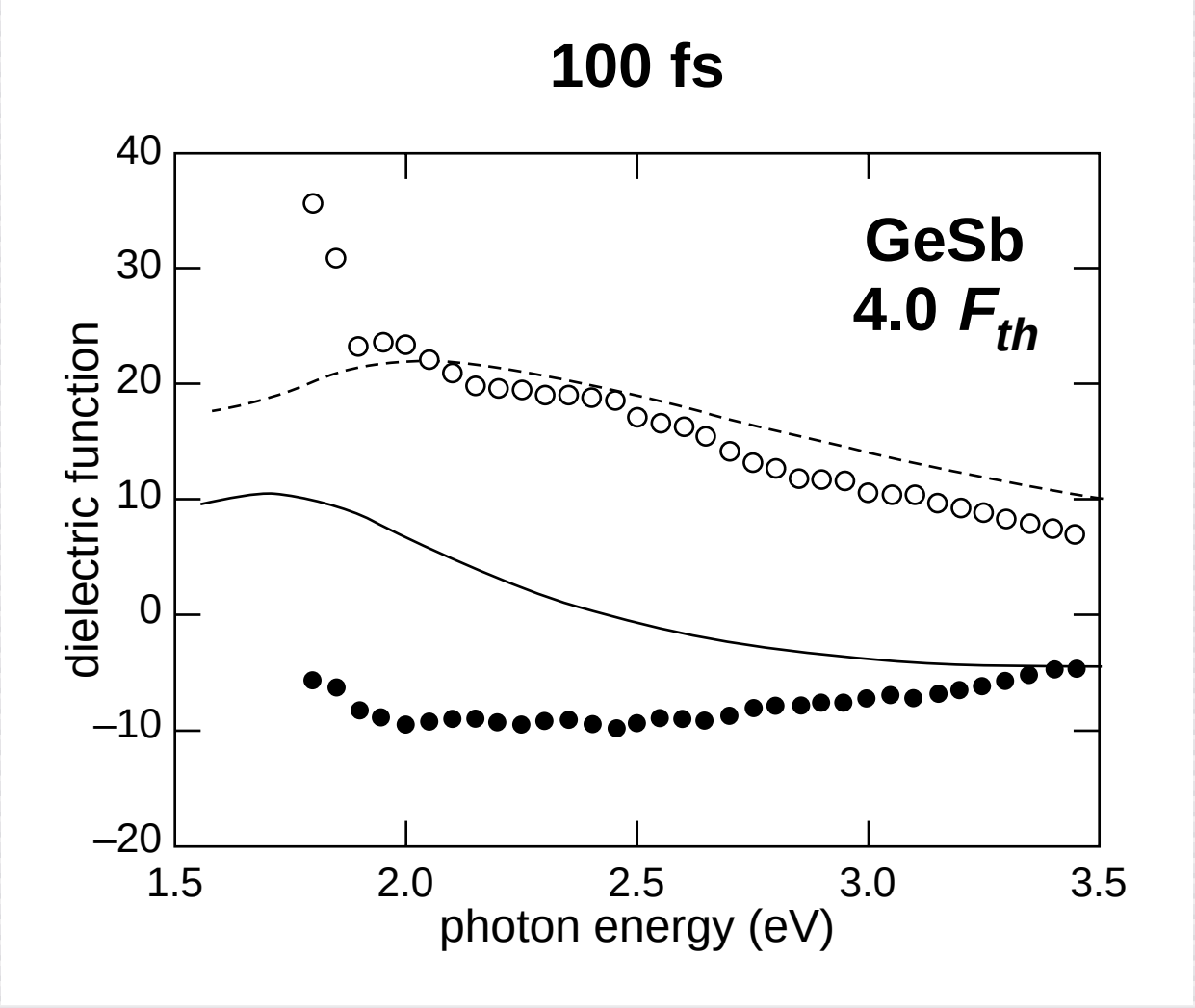
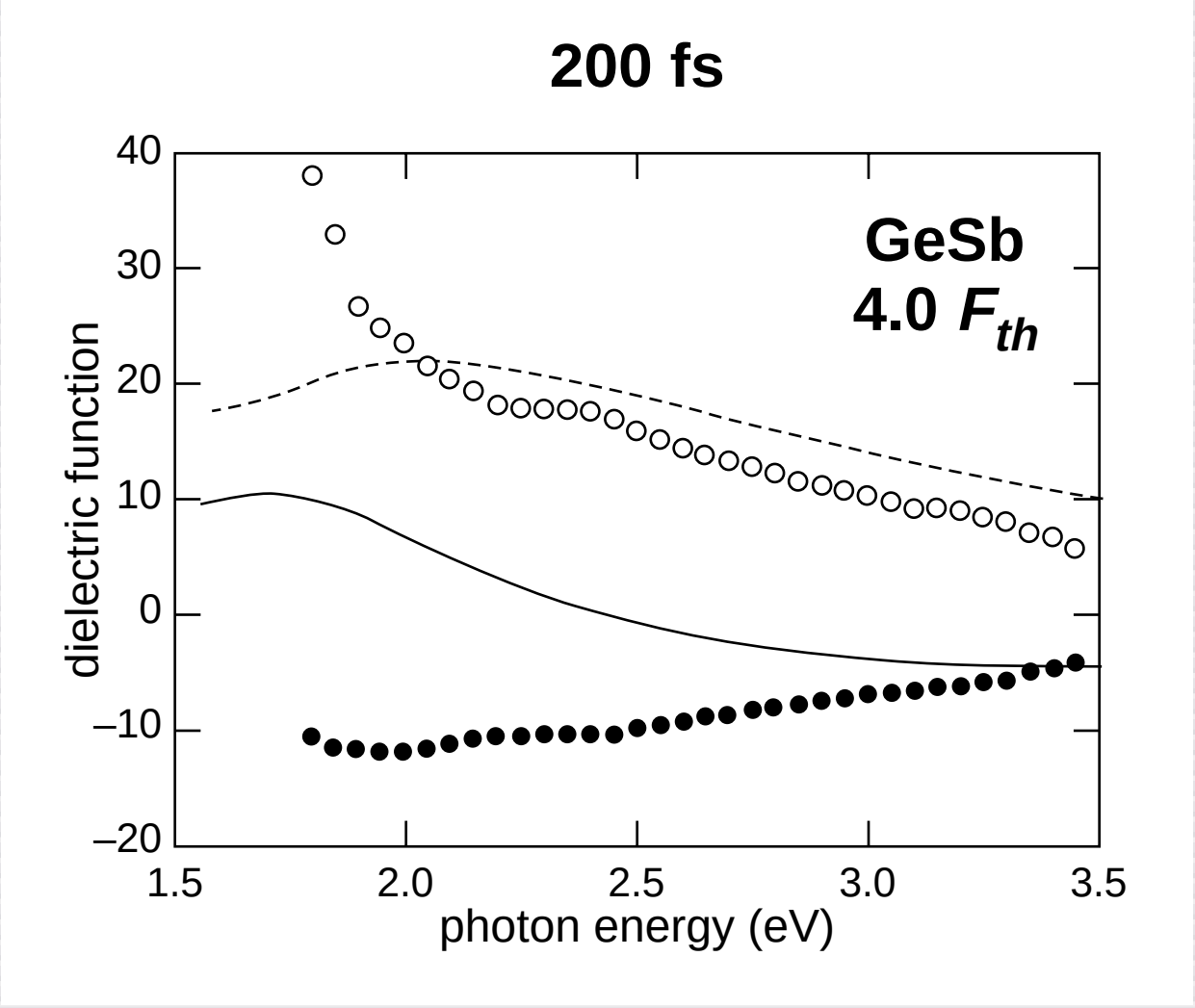

0 ps
GeSb
4.0 F_{th}
dielectric function
photon energy (eV)
40
30
20
10
0
–10
–20
1.5
2.0
2.5
3.0
3.5

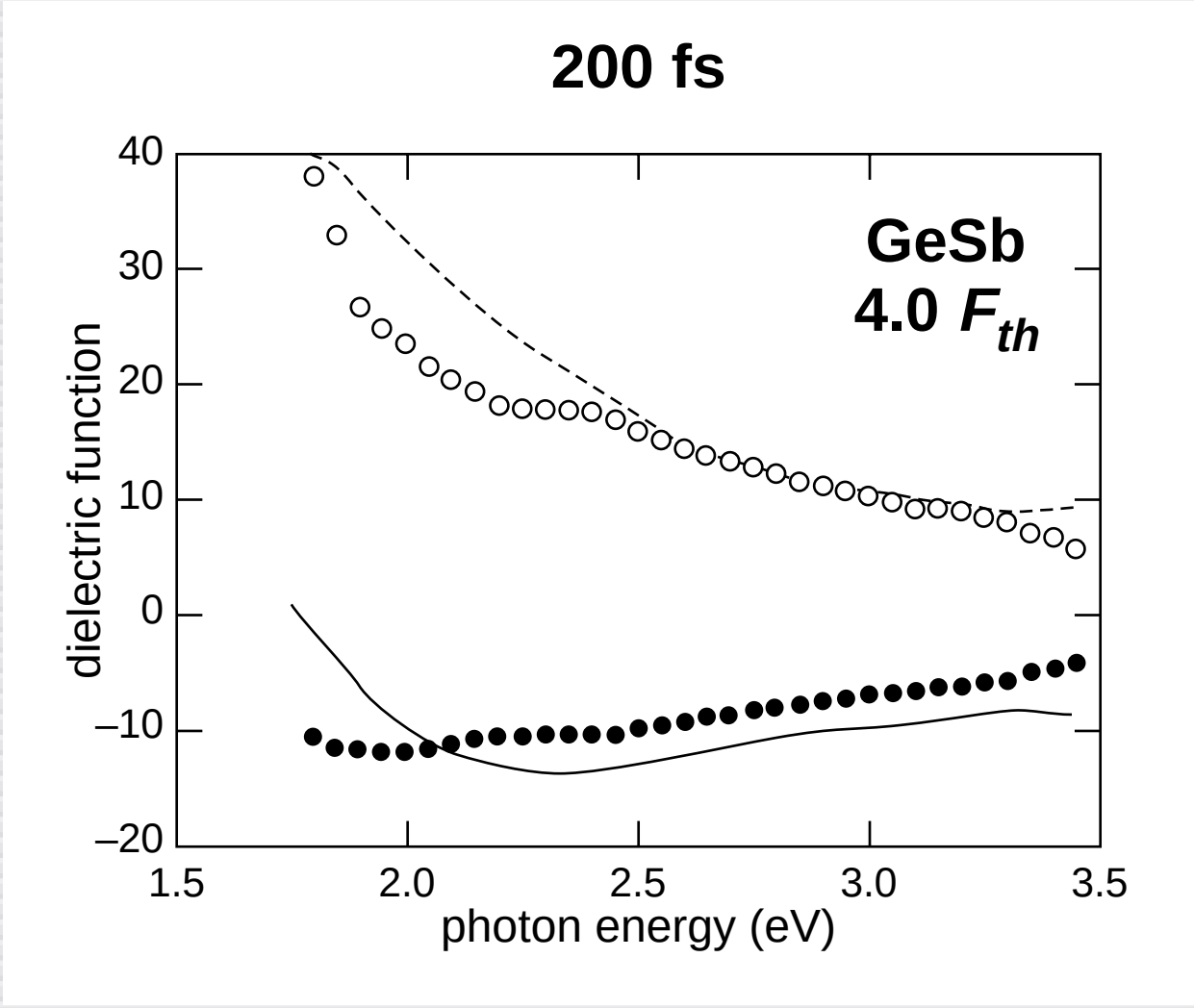
Results


100 fs
GeSb
4.0 F_{th}
dielectric function
photon energy (eV)
40
30
20
10
0
–10
–20
1.5
2.0
2.5
3.0
3.5

Results

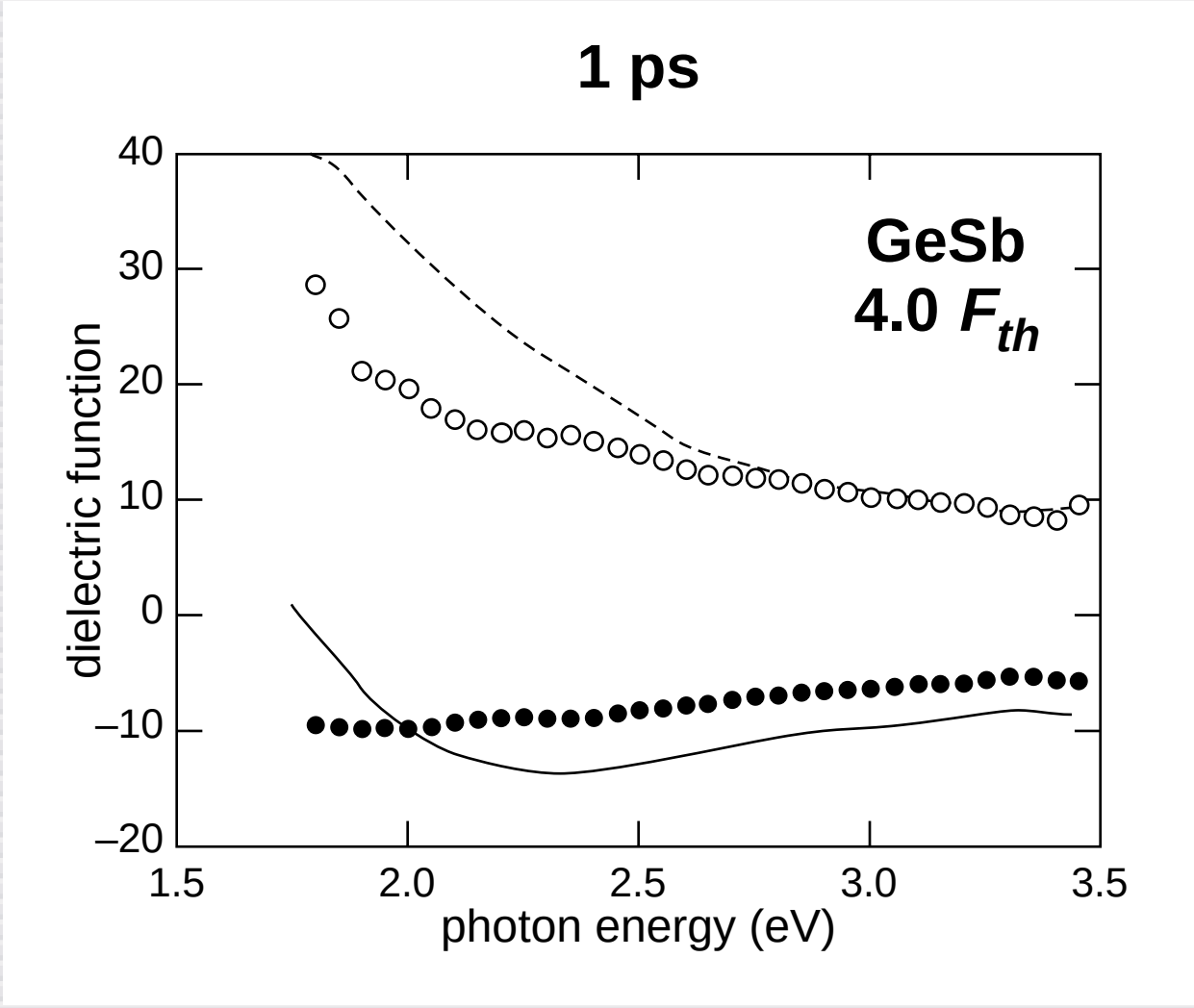

200 fs
GeSb
4.0 F_{th}
dielectric function
photon energy (eV)
40
30
20
10
0
–10
–20
1.5
2.0
2.5
3.0
3.5

Results



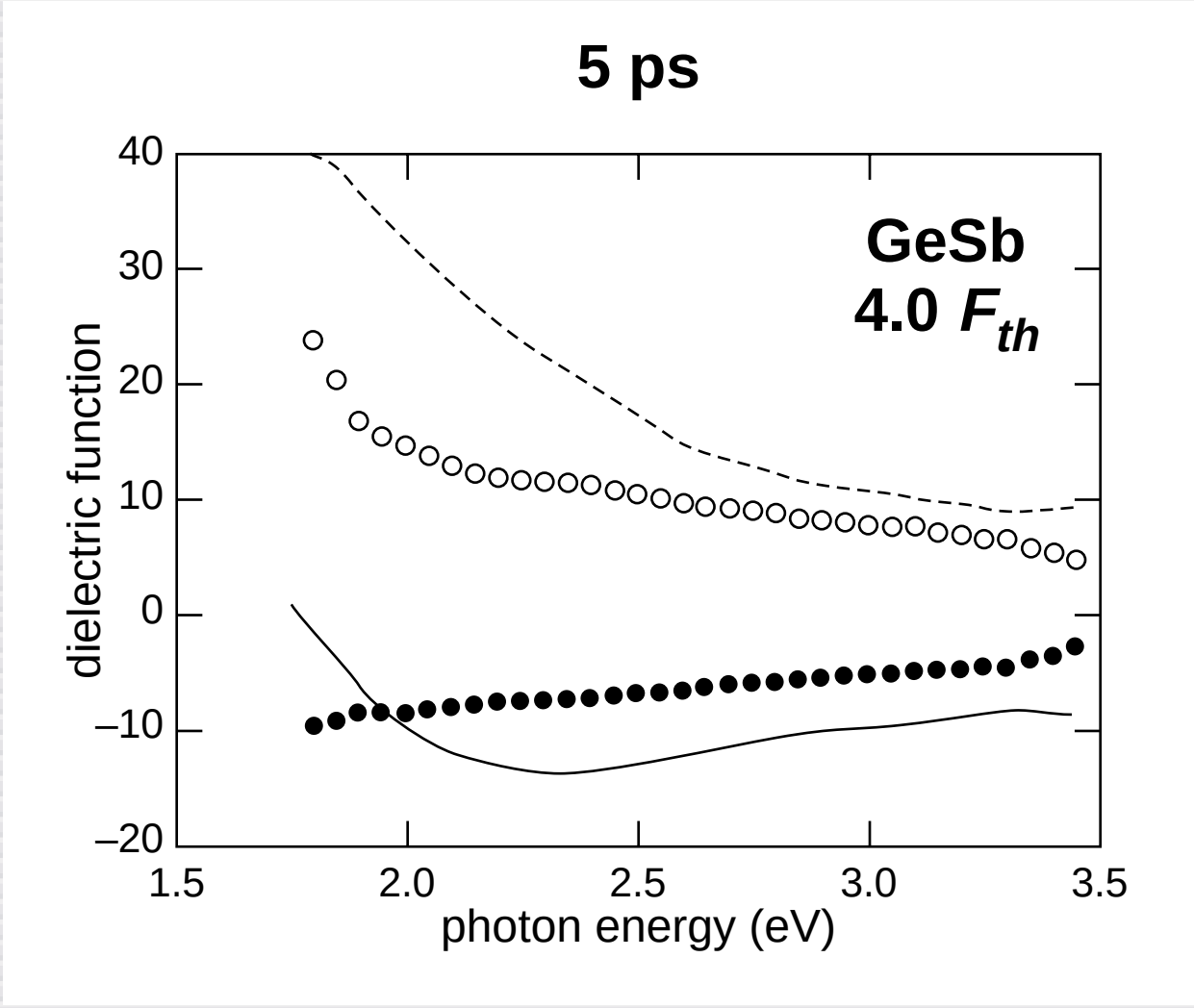
more Drude-like than crystalline

Results



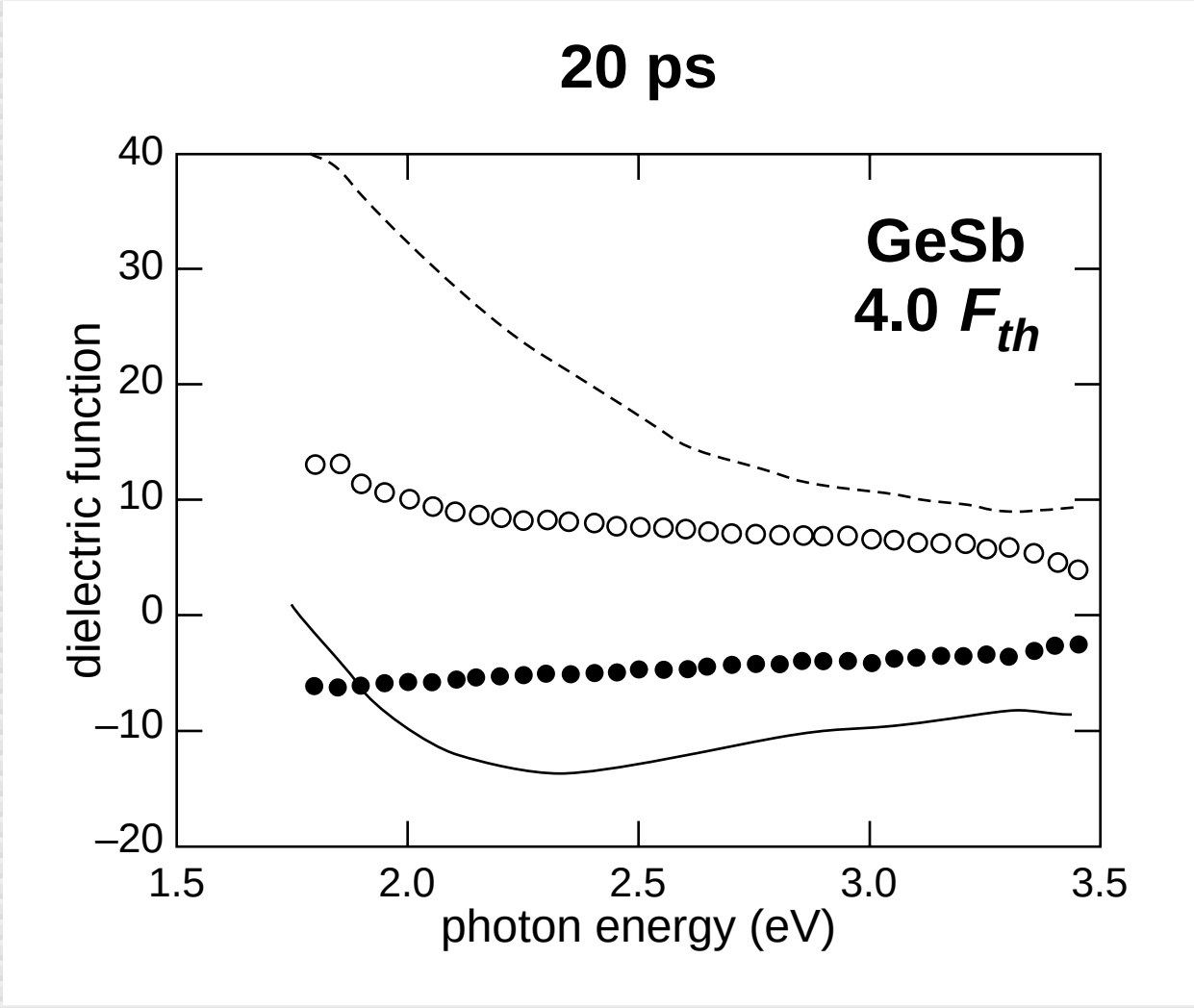
more Drude-like than crystalline

Results



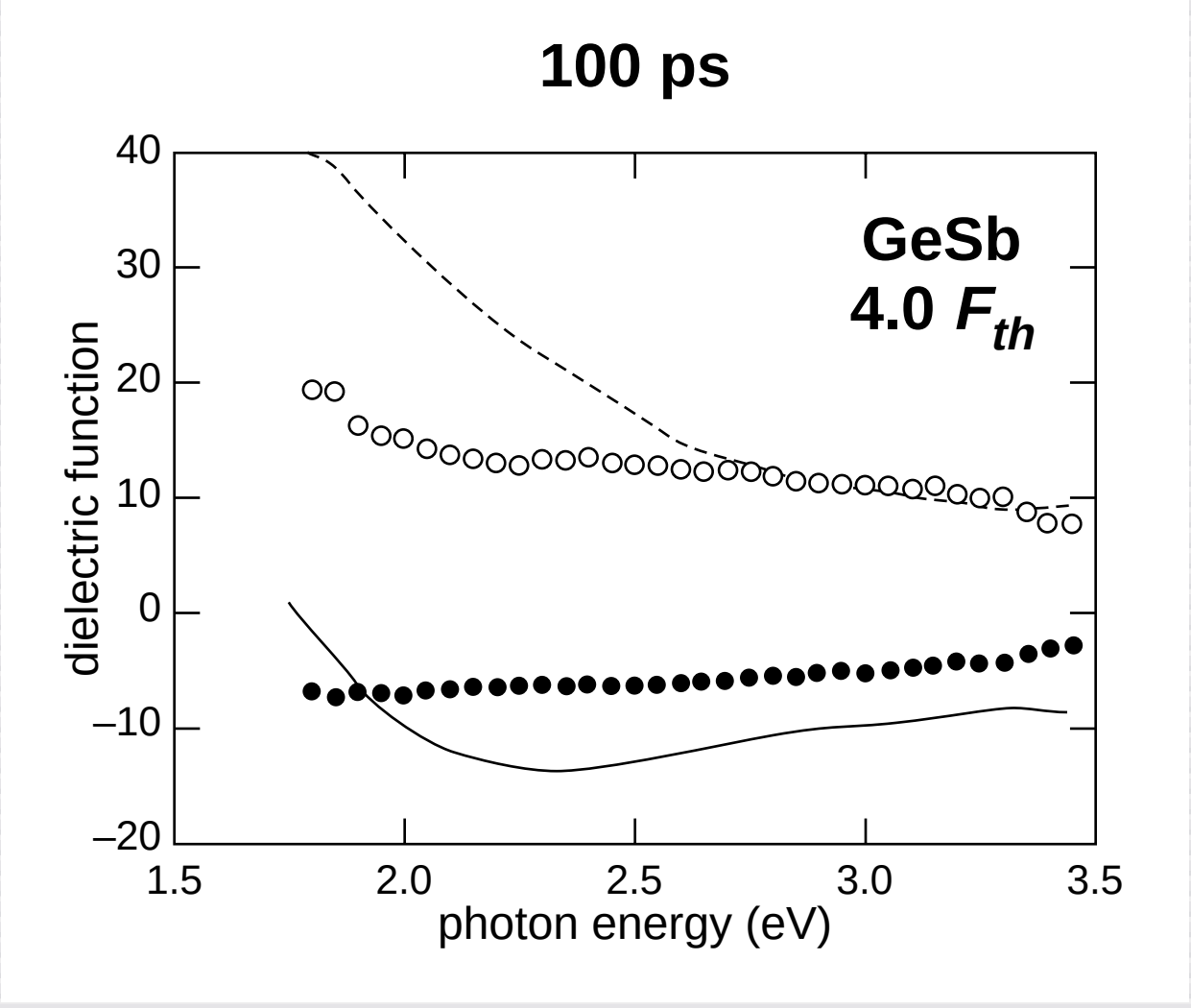
more Drude-like than crystalline

Results



more Drude-like than crystalline

Results


100 ps
GeSb
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dielectric function
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2.0
2.5
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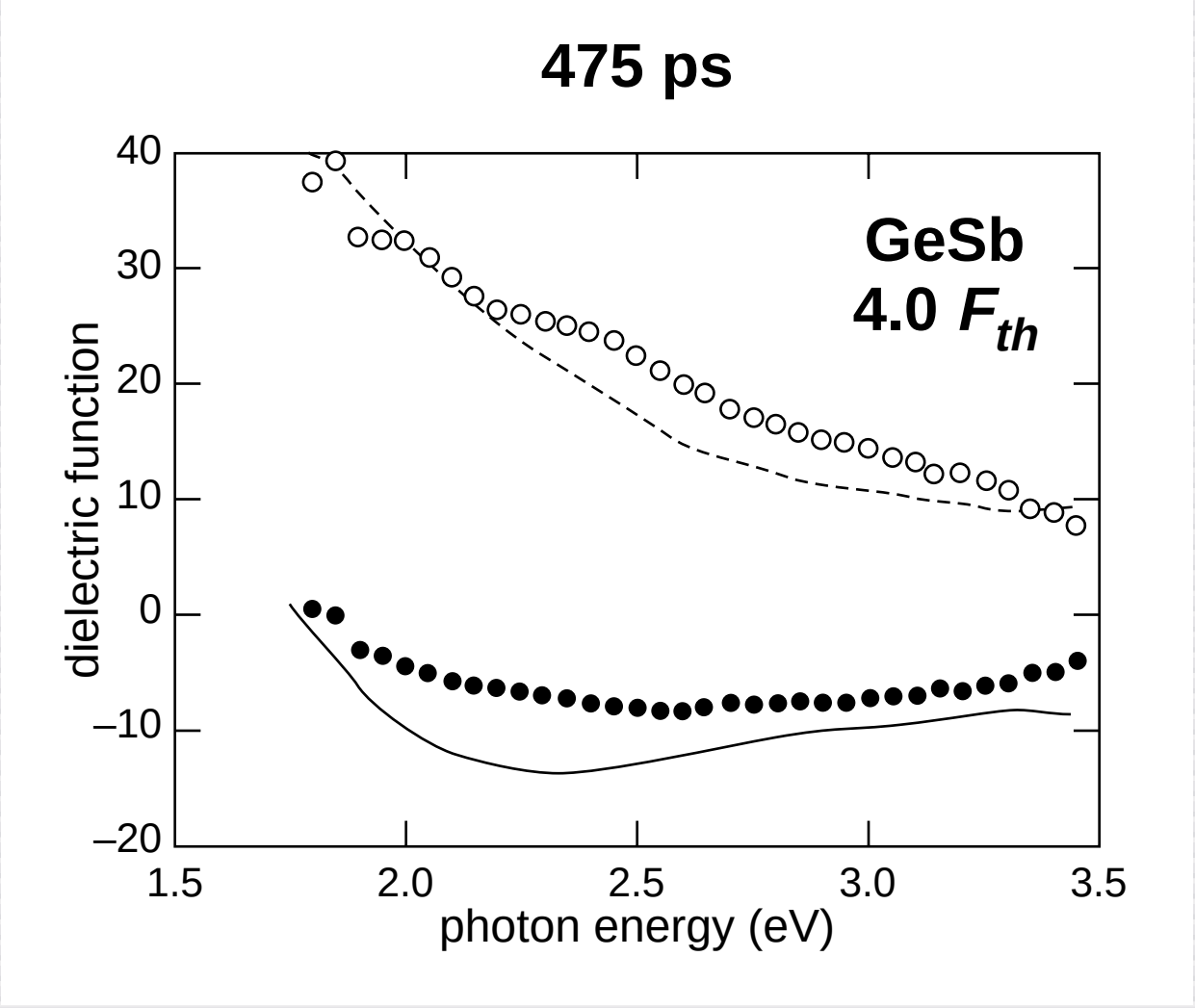
3.5

Results



recrystallization

Summary

- **recrystallization in less than a nanosecond**
- **intermediate phase metallic, but not crystalline**
- **data provide wealth of additional information**

Summary

Femtosecond time-resolved ellipsometry

- **powerful tool for tracking ultrafast electron and lattice dynamics in highly excited solids**

- **helps uncover unexplored terrain on the boundary between condensed matter and plasma physics**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Funding: National Science Foundation

Acknowledgments:
Prof. Dietrich von der Linde
Dr. Klaus Sokolowski-Tinten
Dr. Craig Arnold

For a copy of this talk and additional information, see:

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