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Advances in deep ultraviolet laser based high-resolution photoemission spectroscopy

Key words: Deep and vacuum ultraviolet laser; Second harmonic generation; $KBe_2BO_3F_2$ nonlinear crystal; Photoelectron spectroscopy

Corresponding author: Shen-jin ZHANG
E-mail: zhangshenjin@163.com
ORCID: http://orcid.org/0000-0002-3198-6971

Motivation

1. The deep ultraviolet (DUV, wavelengths below 200 nm) plays a major role in photoemission spectroscopy, Raman spectroscopy, precise micromachining, and many other applications, which benefit from its high photon energy and other merits.

2. The absence of practical and precise DUV light source hindered the development of DUV science and technology.

Main idea

1. KBBF nonlinear crystal and prism-coupled device (KBBF-PCD):

(1) It is the only way by which deep ultra-violet diode pumped solid-state laser (DUV-DPL) can be realized through second harmonic generation (SHG);

(2) The KBBF-PCD patent has been granted by China, the United States, and Japan.

2. Practical, precise, and series of DUV-DPLs:

(1) Series of DUV-DPL prototypes with a fixed wavelength;

(2) Series of DUV-DPL prototypes with a widely tunable wavelength.

3. ARPES prototypes based on DUV-DPL and frontier scientific research:

(1) Super high energy and momentum resolution ARPES prototype;

(2) Spin- and angle-resolved PES (SARPES);

(3) Angle-resolved time-of-flight PES (ToF ARPES) prototype.

1. KBBF nonlinear crystal and prism-coupled device (KBBF-PCD)

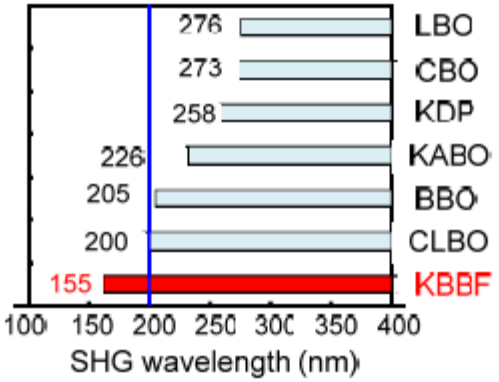


Fig. 1 Second harmonic generation matching wavelengths for typical nonlinear crystals (reprinted from Wang GL et al. (2008), Copyright 2008, with permission from the Optical Society of America)

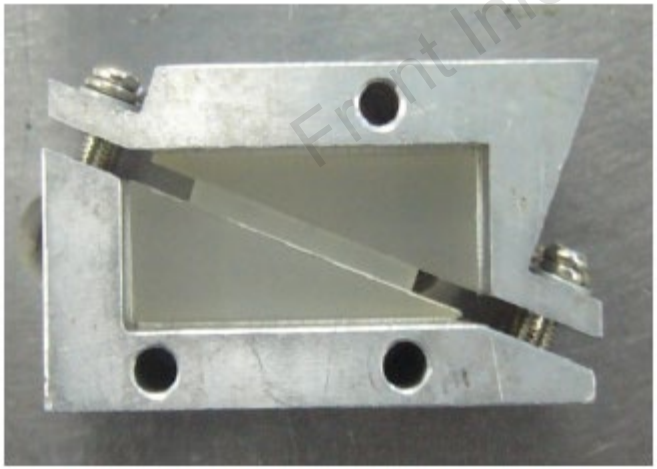


Fig. 3 Photo of the KBBF-PCD entity

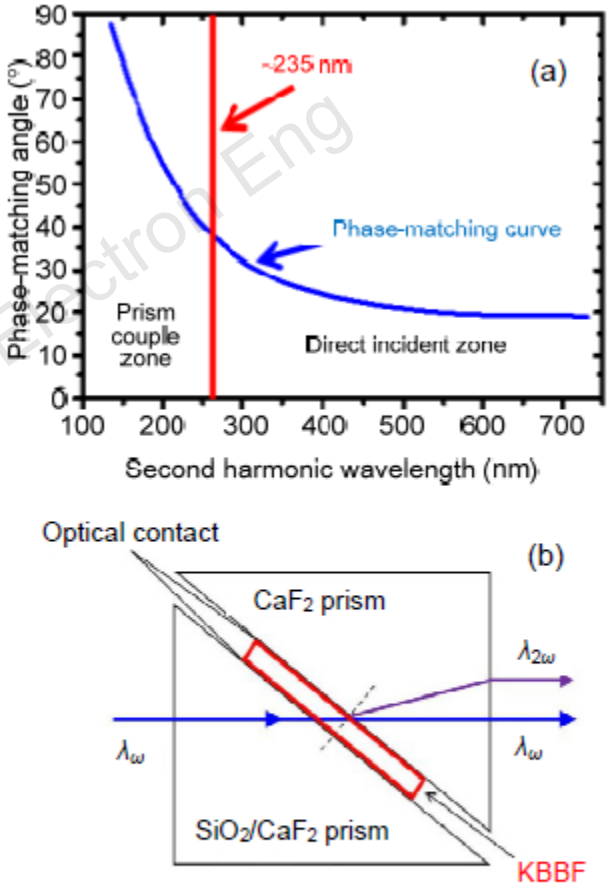
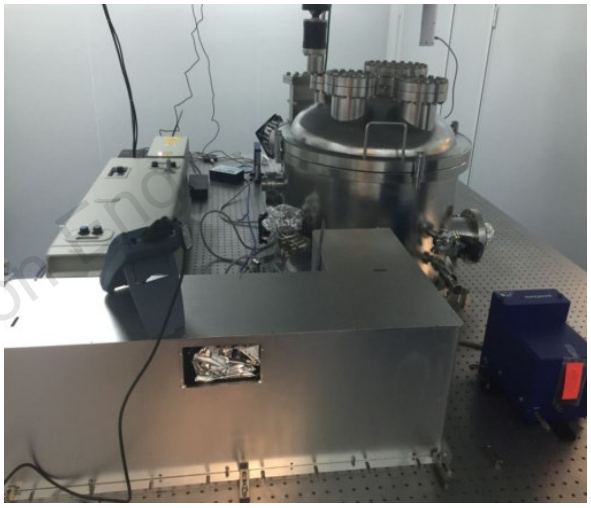


Fig. 2 Second harmonic generation phase-matched curve of KBBF (a) and schematic of a KBBF-PCD (b) (reprinted from Peng et al. (2018), Copyright 2018, with permission from IEEE)

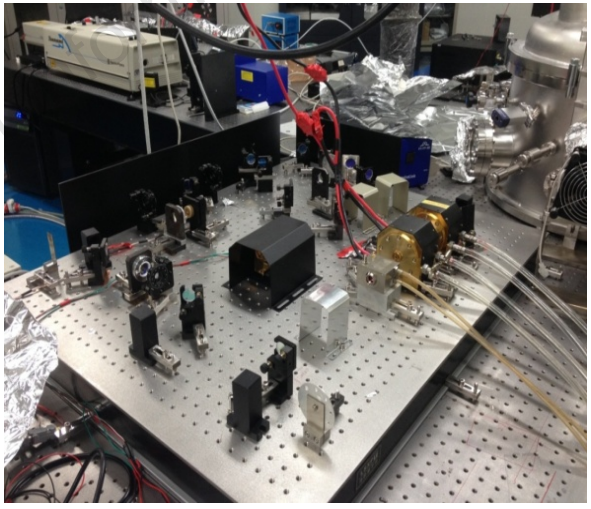
2. China is the only country that can develop practical, precise, and series of DUV-DPLs

Twelve kinds of 21 practical, precise, and series of DUV-DPLs have been developed.

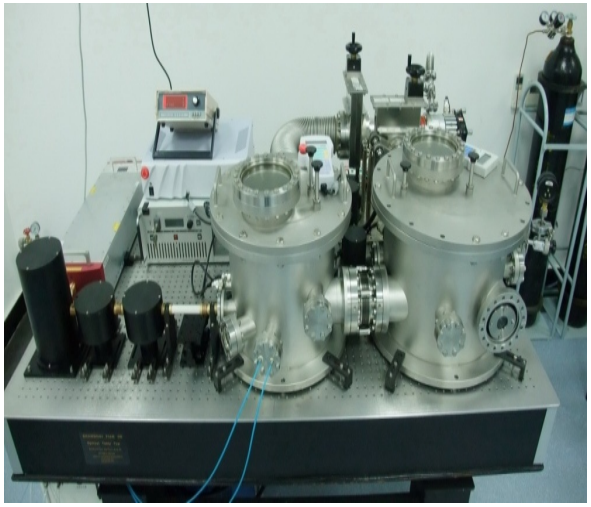
Series of high precision and high accuracy 167.0787 nm DUV-DPL



Series of widely tunable wavelength 170-232 nm DUV-DPL



Series of high pulse repetition rate and short wavelength 164.9 nm DUV-DPL



Series of fixed wavelength 177.3 nm DUV-DPL

3. ARPES prototypes based on DUV-DPL and frontier scientific research

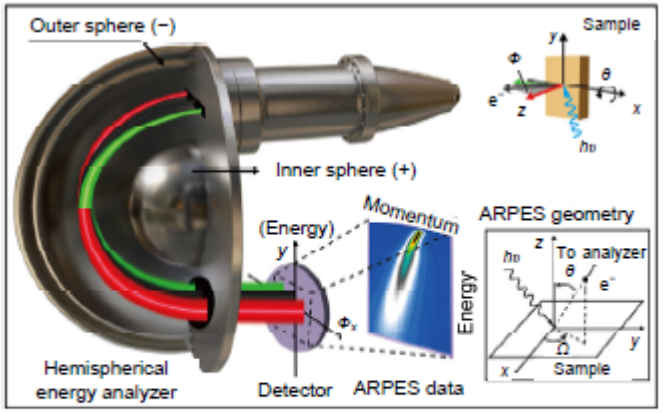


Fig. 28 Principle of a modern ARPES with a hemispherical electron energy analyzer (reprinted from Zhou et al. (2018), Copyright 2018, with permission from the IOP Publishing Ltd.)

Fig. 29 Entity photo of super high energy and momentum resolution ARPES prototype based on DUV-DPL with 177.3 nm fixed wavelength and DUV-DPL with 175–210 nm widely tunable wavelength

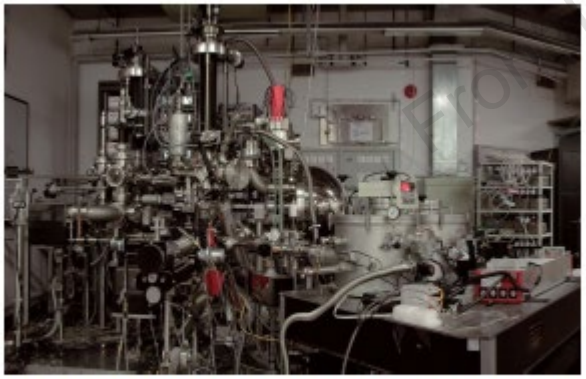


Fig. 30 Entity photo of the SARPES prototype based on arbitrarily adjustable polarization DUV-DPL

Fig. 32 Entity photo of ToF ARPES based on pulse repetition rate adjustable DUV-DPL

Three kinds of angle-resolved photoelectron spectroscopy (ARPES) based on DUV-DPL have been developed.

3. ARPES prototypes based on DUV-DPL and frontier scientific research

(1) New coupling mode and extraction of Eliashberg functions;

(2) Direct observation of spin-orbital locking in topological insulators;

(3) Novel electronic structure of WTe_2 and $ZrTe_5$.

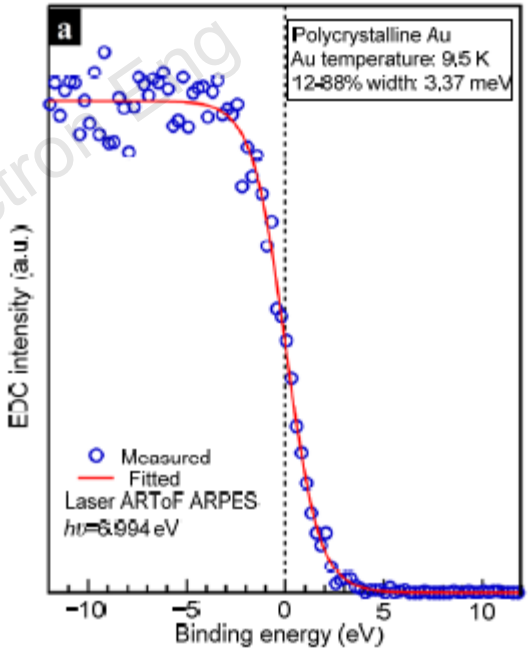


Fig. 33 Experimental results of polycrystalline Au with ToF ARPES (reprinted from Zhou et al. (2018), Copyright 2018, with permission from the IOP Publishing Ltd.)

Conclusions

1. Practical, precise, and series of DUV-DPLs have been developed with KBBF-PCD.

2. Twelve kinds of ARPES prototypes based on DUV-DPL have been developed.

3. A brief account of frontier scientific research has been obtained with ARPES based on DUV-DPL.