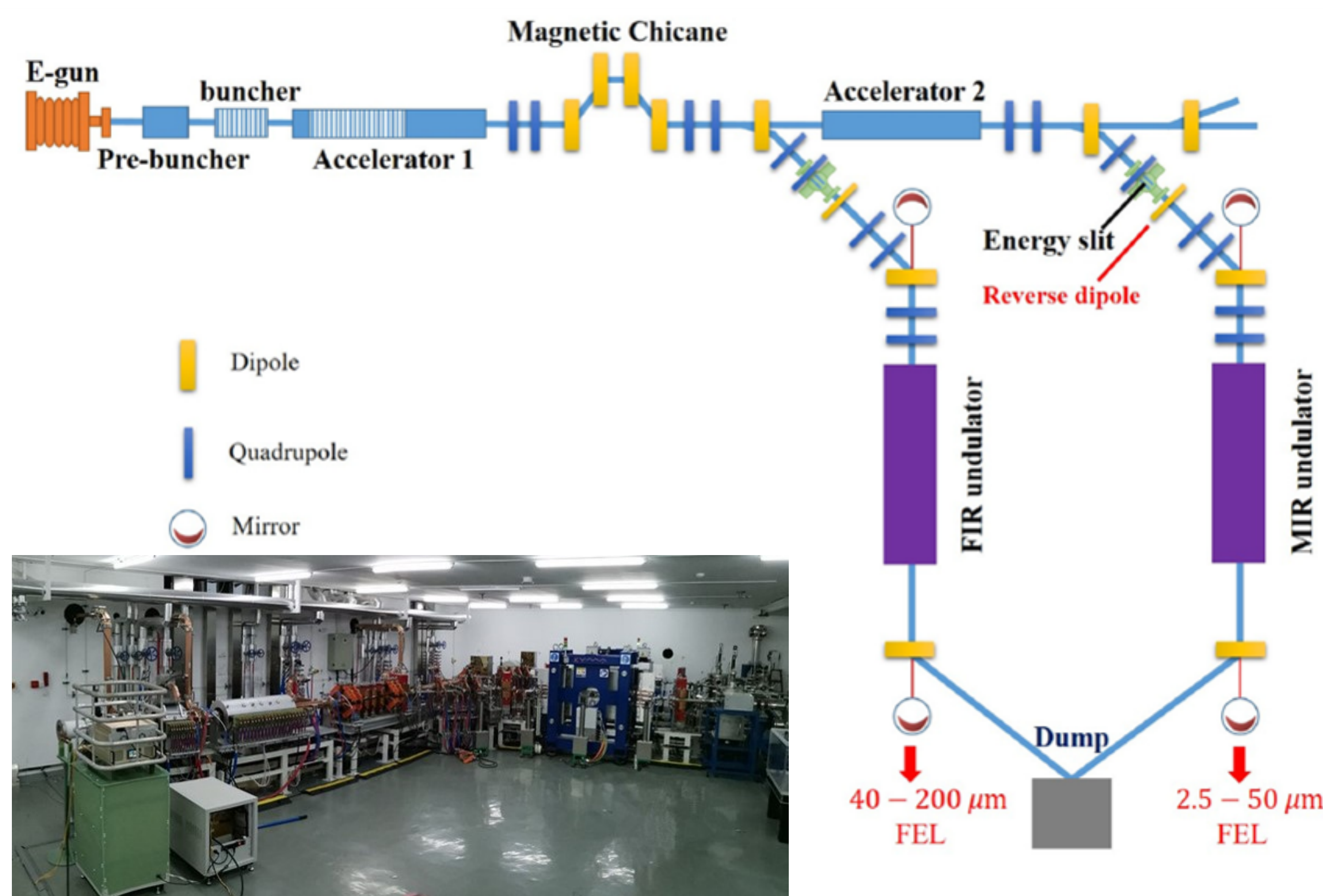


Abstract A phenomenon of spectral gap is observed in the Middle infrared Free-electron laser oscillator (FELO) of FELiCHEM: the laser power falls down at the particular wavelength. Starting with the experimental data, this paper focuses on the simulation calculation and the effect from using the partial waveguide. The relationship between waveguide gap and spectral gap is revealed.

Introduction

Free-electron laser oscillators (FELOs) have been around since 1977. Spanning the wavelength range from the millimeter region to the ultraviolet, dozens of FELOs are presently operating around the world. FELiCHEM is a facility for energy and chemical scientific researches constructed by the National Synchrotron Radiation Laboratory (NSRL) in China. Two FELOs driven by one radio frequency linear accelerator are used to generate mid-infrared (MIR)(2.5-50 μm) and far-infrared (FIR)(40-200 μm) lasers.

A phenomenon of spectral gap was observed in the MIR FELO of FELiCHEM when in commissioning and operation. The output laser power falls down quickly and even be nearly disappeared around the particular wavelength region. In this paper, we probe into the causes and rules of spectral gap.



Experimental Data of MIR FELO in FELiCHEM

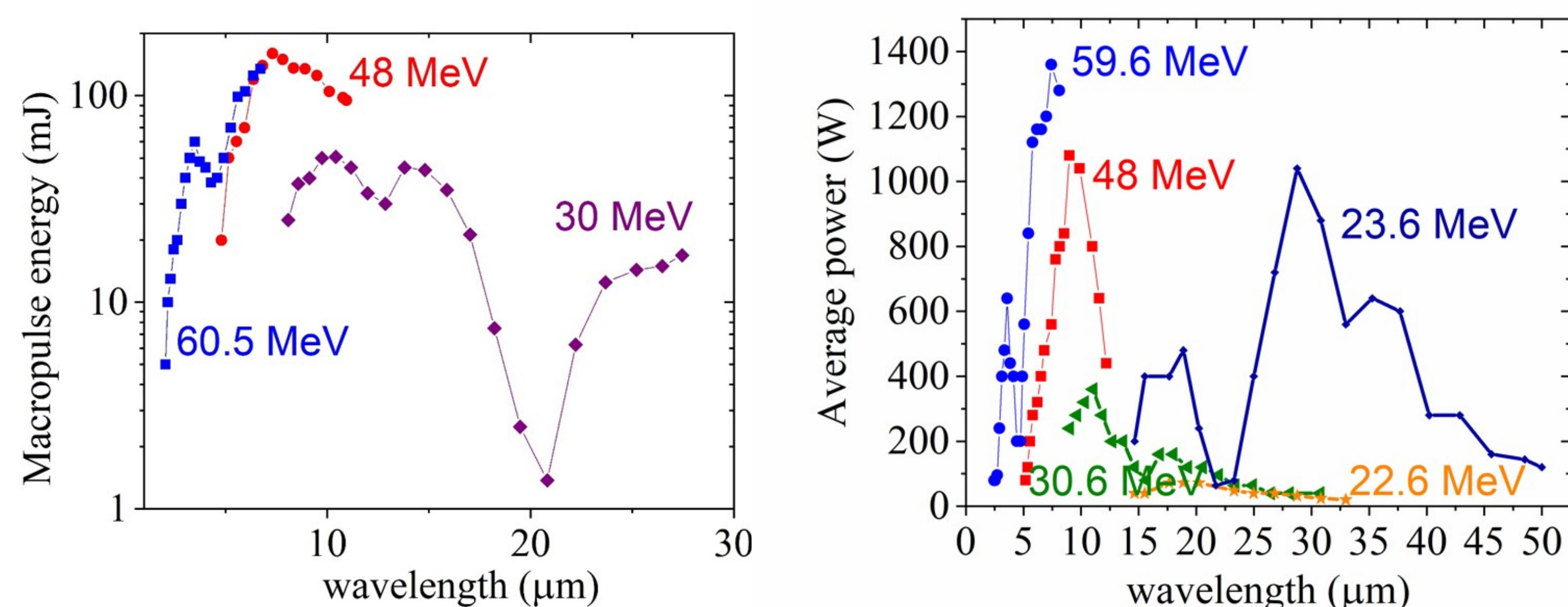
A phenomenon of spectral gap was observed in the MIR FELO of FELiCHEM. Obviously, macropulse energy of the output laser dramatically decreases to the lowest at the wavelength of 20.5 μm . In term of the average power, the existence of spectral gap around 20 μm can also be clearly seen.

✓ Fig. A: Macropulse energy of FELiCHEM middle infrared laser (measured by energy meter in Nov.2020)

(waveguide(a $\times$ b): 35 $\times$ 10 mm).

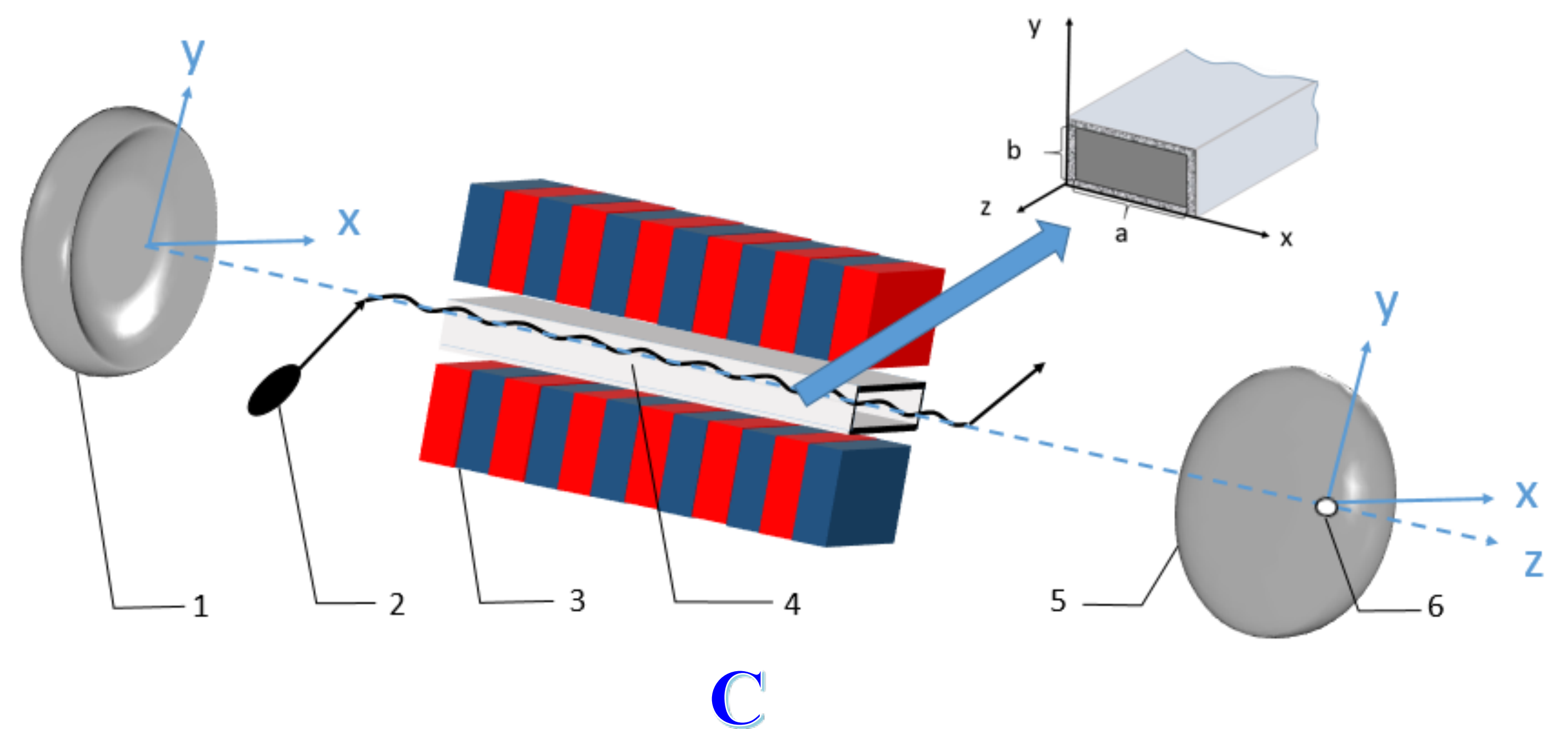
✓ Fig. B: Average power of FELiCHEM middle infrared laser (measured by power meter in Jun.2020)

(waveguide(a $\times$ b): 20 $\times$ 10 mm}).



A

B



Explanation and Simulation

The wavelength position formula of spectral gap:

$$\lambda = \frac{b^2}{2L} (2n + 1) \quad n = 0, 1, 2, \dots$$

It can be calculated theoretically that the wavelength at the spectral gap within the operating wavelength range is 20.8 μm .

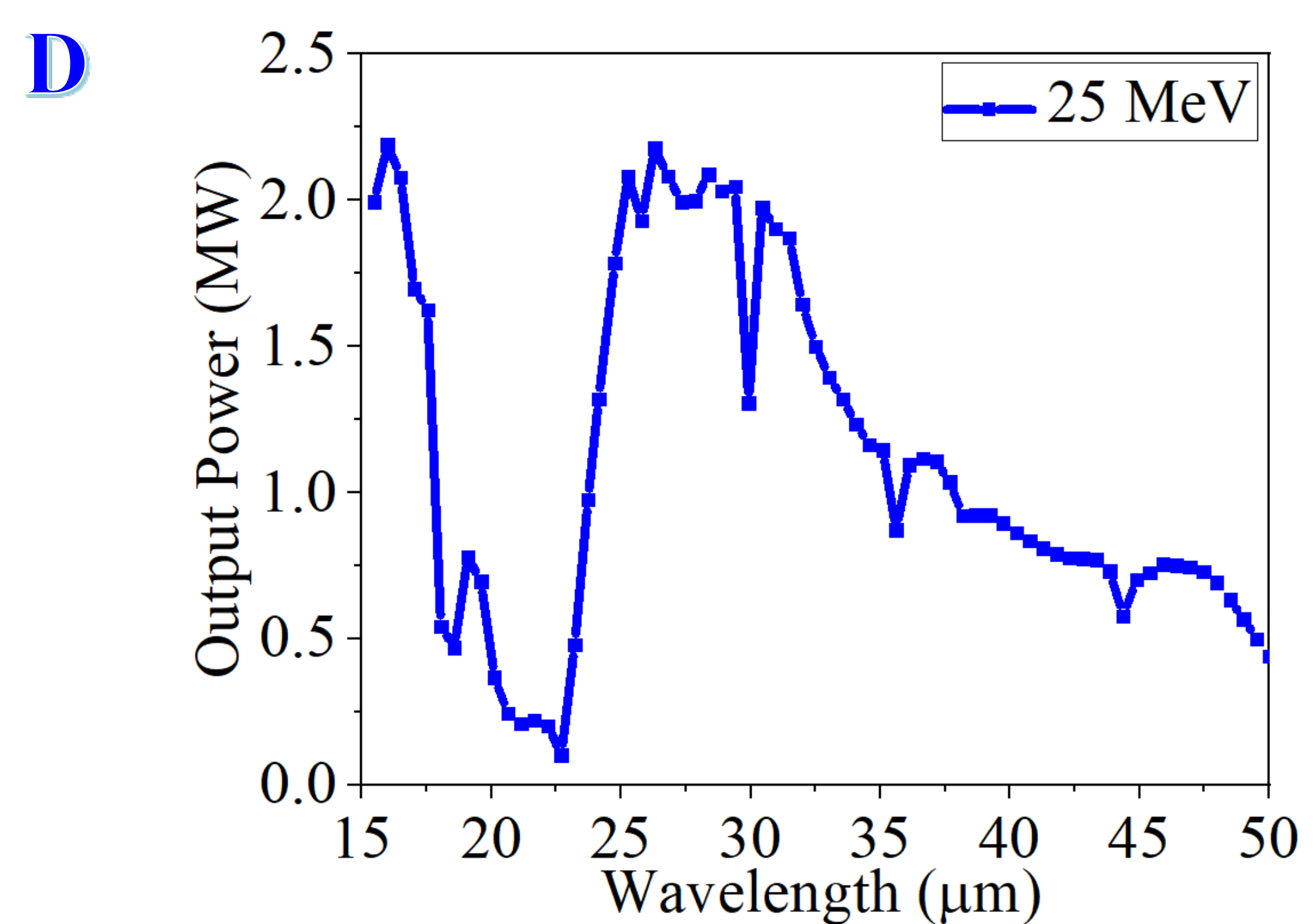
The agreement between experiment, simulation and theoretical formula calculation is acceptable. What they have in common is that the position of spectral gap ($\lambda = 20 \mu\text{m}$) is determined by the waveguide gap ($b = 10 \text{ mm}$).

With the energy of injected electron beam is 25 MeV, there is a spectral gap around the wavelength of 20 μm .

✓ Fig. C: Schematic of FELiCHEM's MIR FELO layout.

✓ Fig. D: Simulation of FELiCHEM middle infrared laser (waveguide(a $\times$ b): 30 $\times$ 10 mm)

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Conclusion

This phenomenon widely exists in FELO with waveguide, and the position of spectral gap can be determined after the structure parameters of the device are set. This phenomenon affects user experiments such as spectral scanning. In FELiCHEM middle infrared laser, the spectral gap where the output laser energy and power are greatly reduced is around 20 μm .