Quantum Cascade Laser

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What kind of a laser is this Quantum Cascade Laser ?

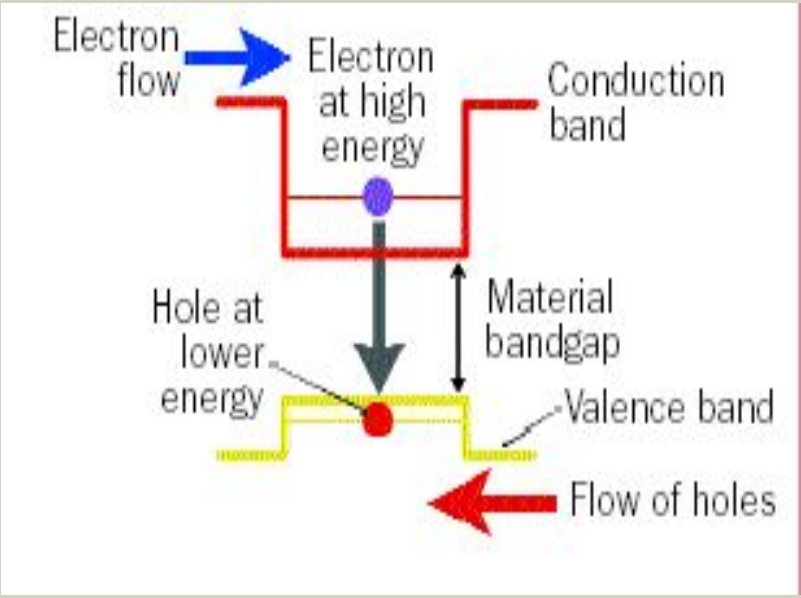
- This is a semiconductor laser.
- But the characteristics of this laser are different from the conventional semiconductor lasers.

How do conventional semiconductor lasers work ?

- A semiconductor absorbs light when electrons are excited from the valance band to the conduction band.
- Light is emitted when those electrons drop into the valance band.

Construction of the conventional semiconductor laser

- It has the active region which consists of two semiconductor materials forming a p-n junction
- The injected electrons and holes in the active region recombine and create photons.



Disadvantage of the conventional semiconductor laser

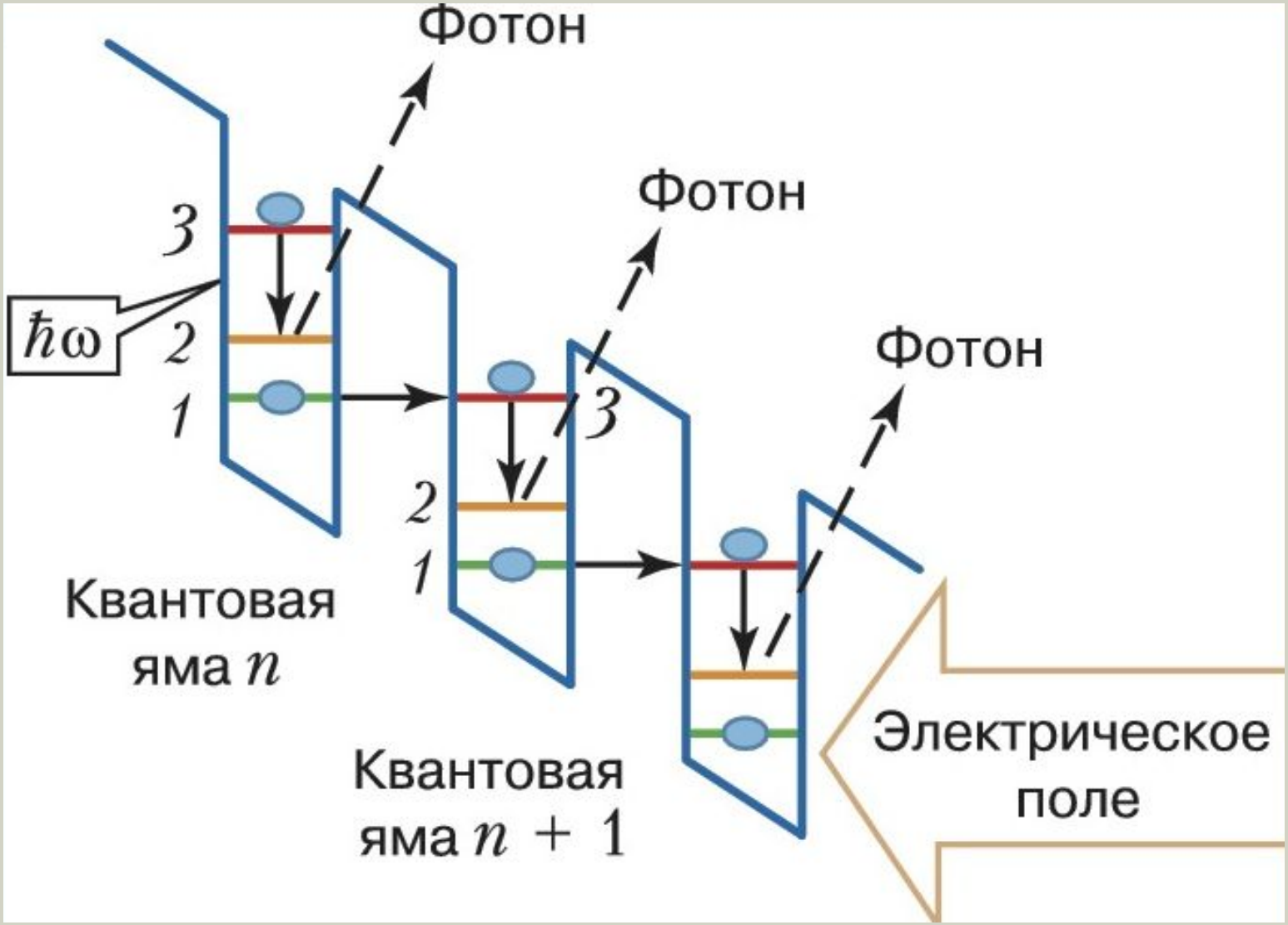
- The band gap decides the wavelength of the laser. so to get the laser with different wavelength we have to choose a different material.
- once an electron has emitted a laser photon by jumping from the upper to the lower energy level, it remains in the valence band.

how quantum cascade laser differs ?

- QC lasers rely only on the one type of carrier, they are the electrons.
- So they are also called the unipolar lasers.
- Photon emission therefore relies on intraband transitions between quantized conduction band states in coupled quantum wells.

Quantum wells

- Quantum wells are ultra thin sandwiches of two different semiconductors.
- A quantum well is essentially a semiconductor with relatively low band gap energy sandwiched between semiconductor layers with high band gap energies
- the thickness is typically a few nanometers, and electrons are confined primarily to the center part of the sandwich.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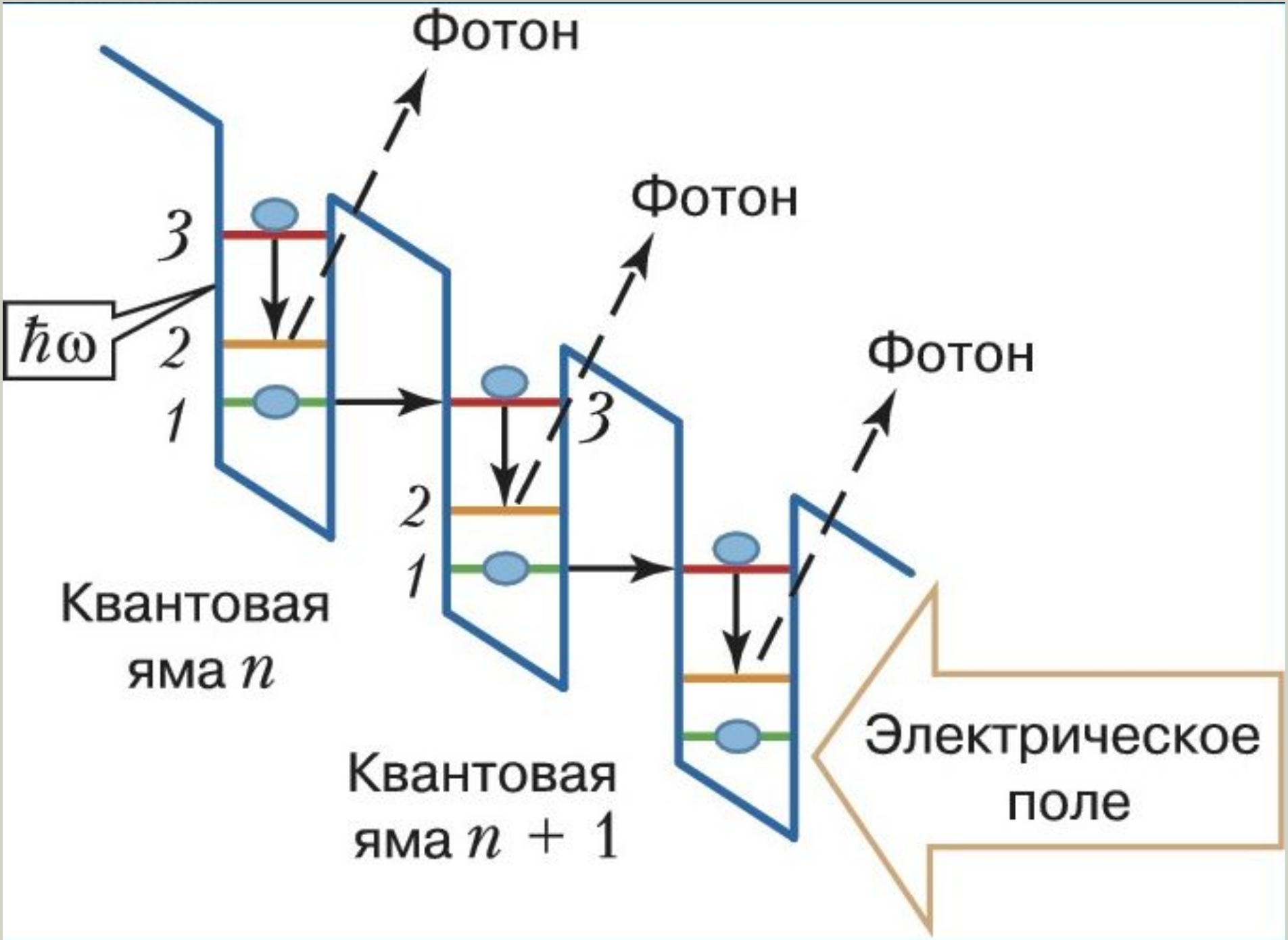
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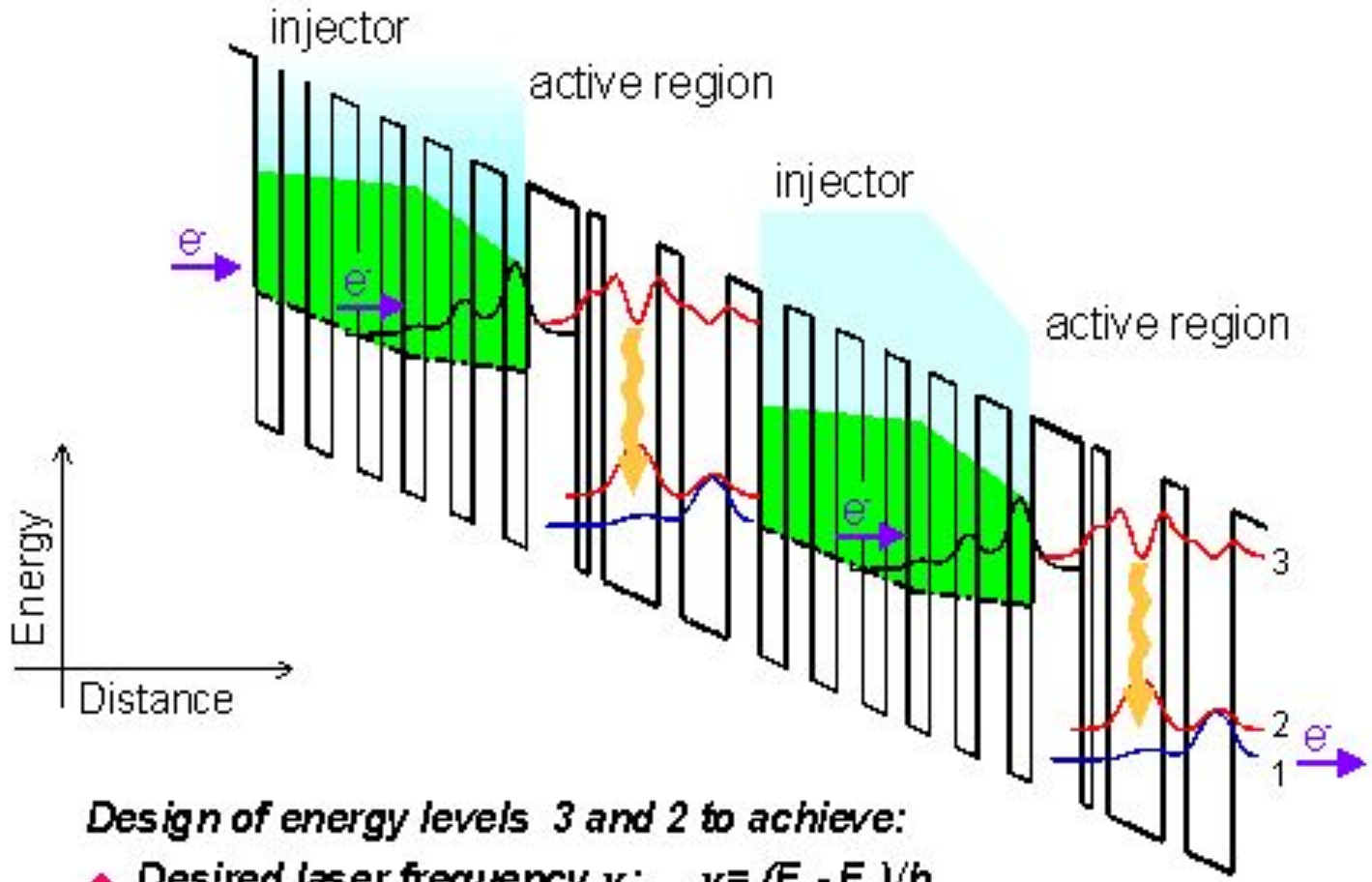
Электрическое поле

Quantum design of QC-laser

J. Faist, F. Capasso, C. Sirtori, D. L. Sivco, J. N. Baillargeon, A. L. Hutchinson, S. N. G. Chu, and A. Y. Cho, Appl. Phys. Lett. ***68****, pp. 3680-3682 (1996).*



Design of energy levels 3 and 2 to achieve:

- ***Desired laser frequency ν:*** $\nu = (E_3 - E_2)/h$
- ***Light amplification: level 3 full of electrons; level 2 empty of electrons***

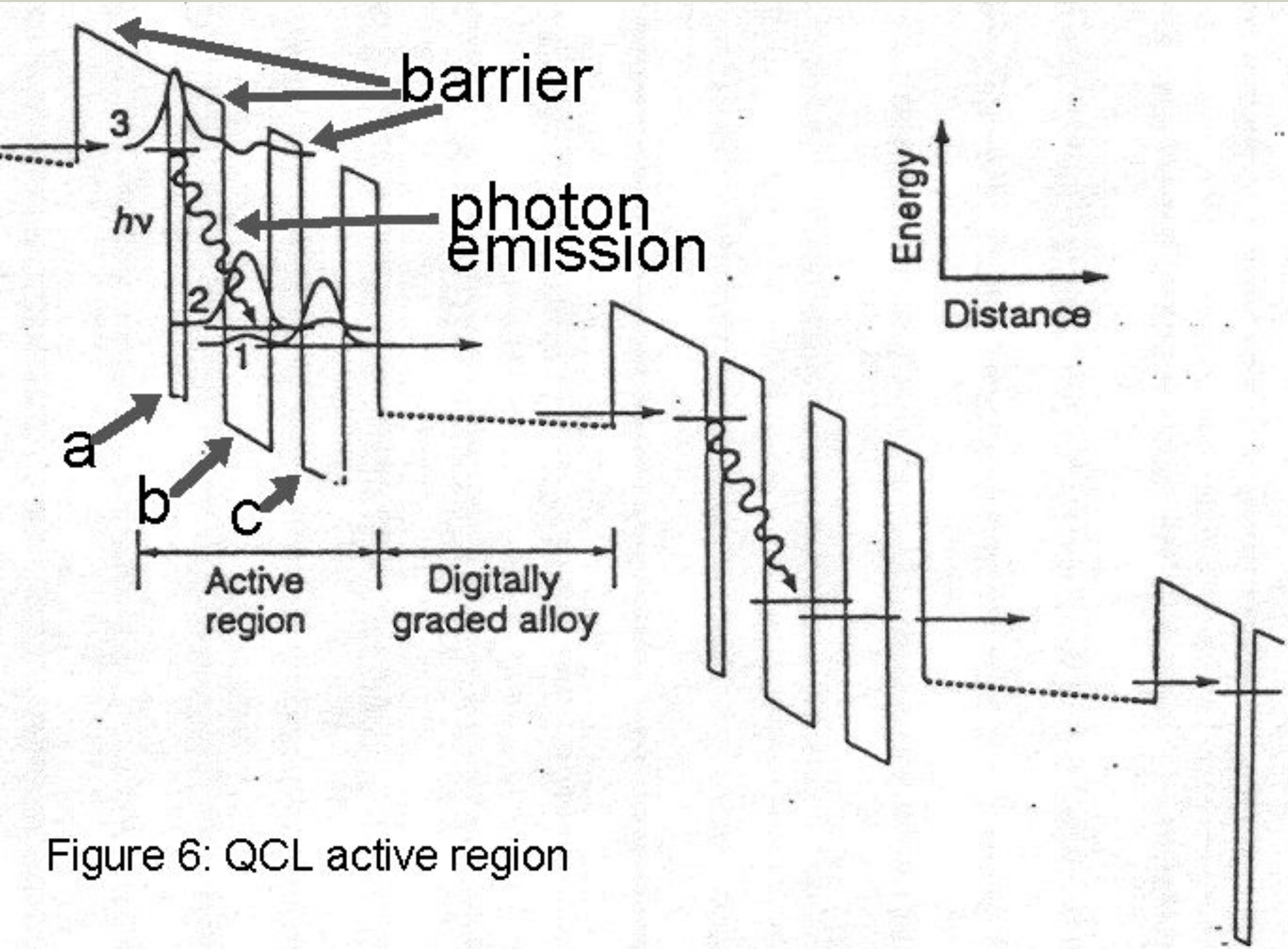
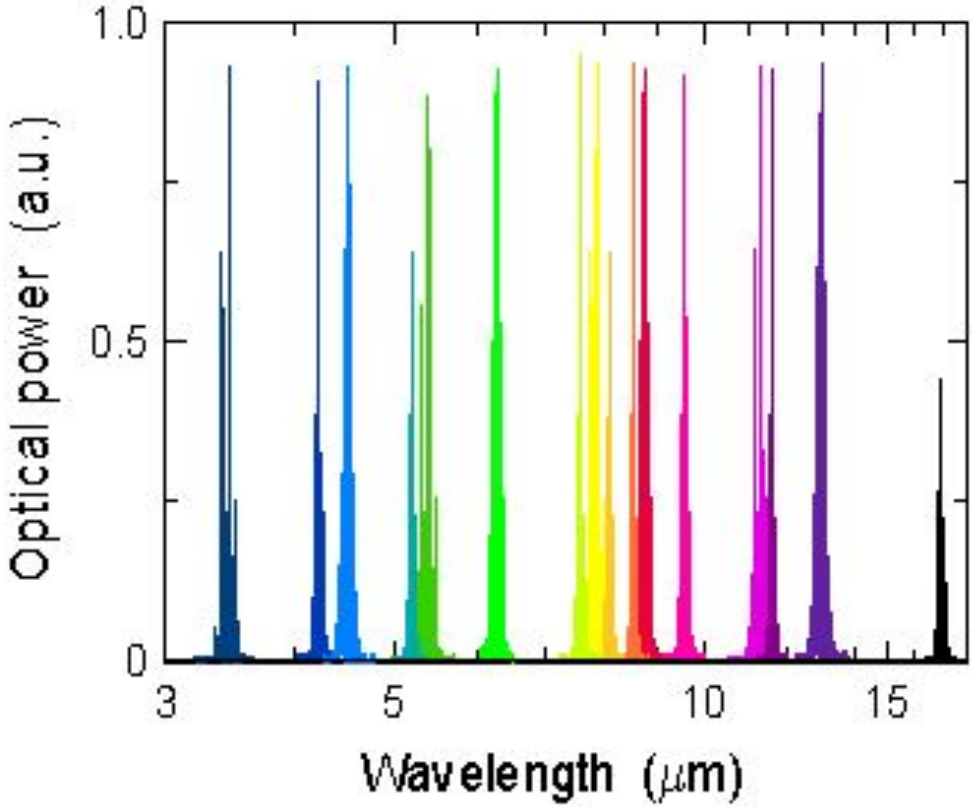


Figure 6: QCL active region

characteristics

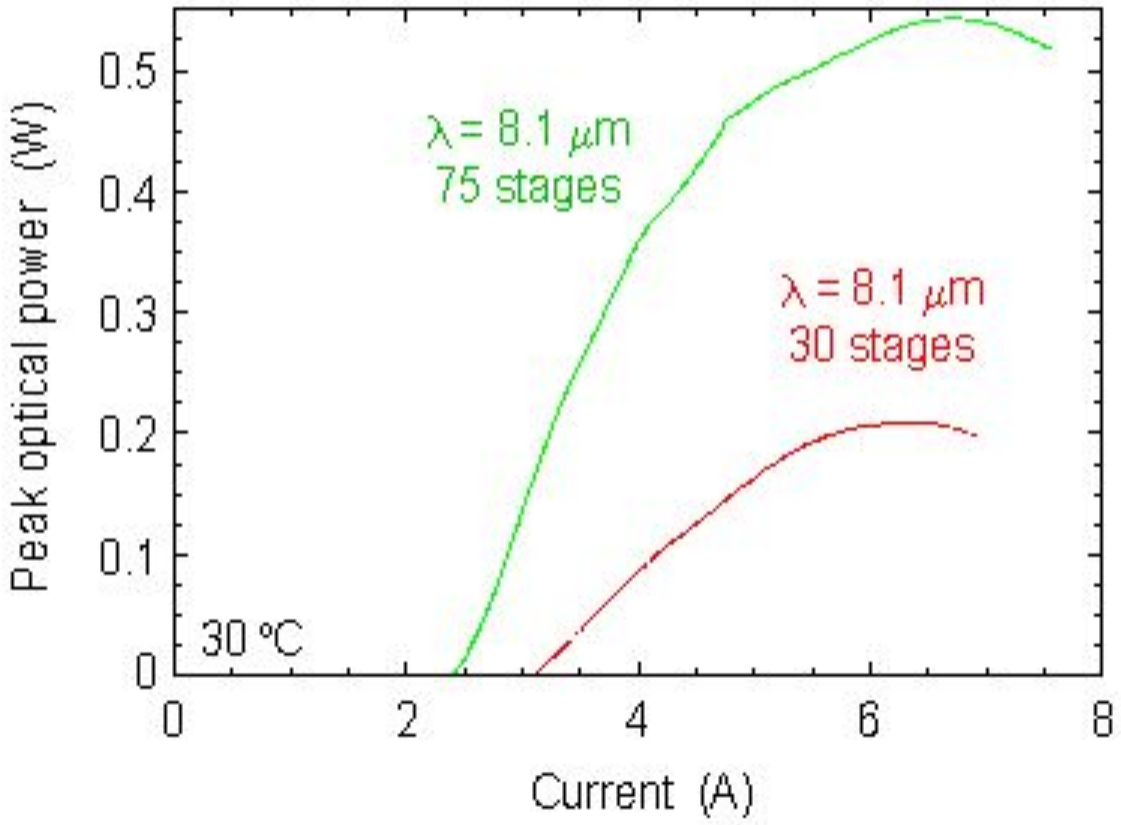
- Wavelength determined by thickness rather then by the material.
- All mid infrared covered by the same material. This important spectral range has so far been accessible mainly with relatively unreliable and expensive lead salt based diode lasers.
- Each electron creates N photons when it traverse N stage cascade structure.
- High power lasers.
- Low failure rate, robust fabrication and long life time.

Wide wavelength-range of QC lasers



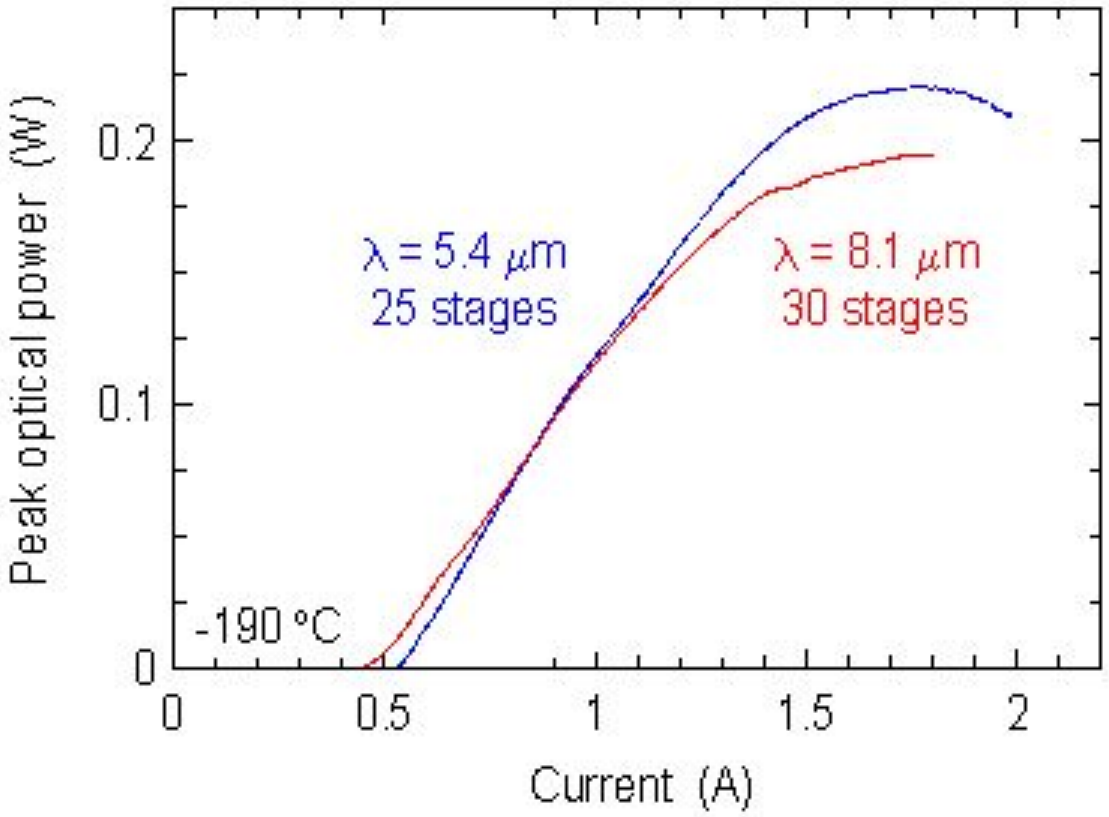
QC lasers cover entire mid-infrared wavelength range (3.4 - 17 μm) by tailoring layer thicknesses of the same material

High power, room temperature QC lasers operating in pulsed mode



- **0.2 W peak power** for wavelength range $\lambda \approx 5 - 9\ \mu m$
- very high power generated by increasing number of stages (up to 75)

High power, liquid nitrogen cooled QC lasers operating in continuous mode



- **0.2 W average power** for wavelength range $\lambda \approx$ 5 - 8 μm
- **maximum operating temperature in continuous mode:** -100 °C

Applications

- Environmental sensing and pollution monitoring- point sensors, LIDAR
- Industrial process control.
- Automotive- cruise control, collision avoidance radar.
- Medical- breath analyzer, early detection of ulcers, colon cancer
- Military applications.

Thank you