Test and assessment of a new quantum cascade laser at 23 µm for applications in the longwave infrared region

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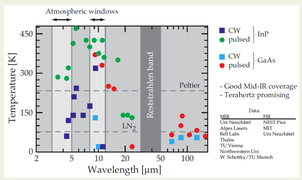
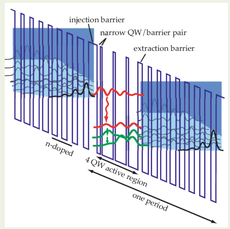
Abstract

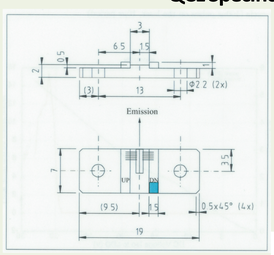
We report the preliminary test results of a quantum cascade laser (QCL) at 23 µm (430 cm^{-1}) with average power < 1 mW. It operates in a pulsed multimode around LN_2 temperature in a cryostat. After installation, the pulsed QCL at 23 µm was tested using $LiNbO_3$ pyroelectric detectors in a method with gate signal. The characterization of the QCL at 23 µm includes dependence of output power on voltage, stability of power and operating temperature, beam profile, and spatial distribution of the beam. The average power of the laser is estimated based on the spatial distribution results.

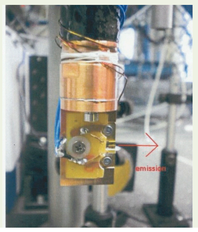




Description of QCL at 23 µm

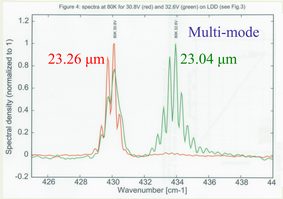
QCL Specification

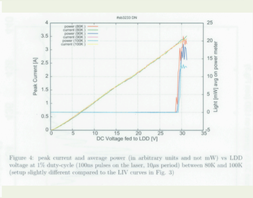


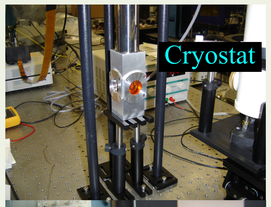


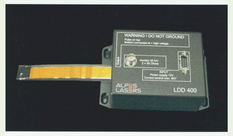
QCL holder and emission direction

Ref.	Désignation	Qté.
Ref.	*Designation*	*Qty.*
9115	LN2-P-FP-QCL-xxx-430	1
High power Cryogenic temperature pulsed Multimode emission centered at 430 cm-1 from stock. Average Power <1 mW @ 80K		

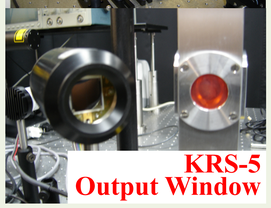








Laser driver



Pulse generator

Photographs of the system

Introduction of System

Cryostat system:
A continuous flow research cryostat from 1.5 K to 325 K using LHe or LN_2
Cryostat head, Laser holder, Cryo-shield, Cryostat cap, Output window (KRS-5 for optimal transmission at 23 µm), Temperature controller

23 µm QCL, pulser, driver, and power supply:

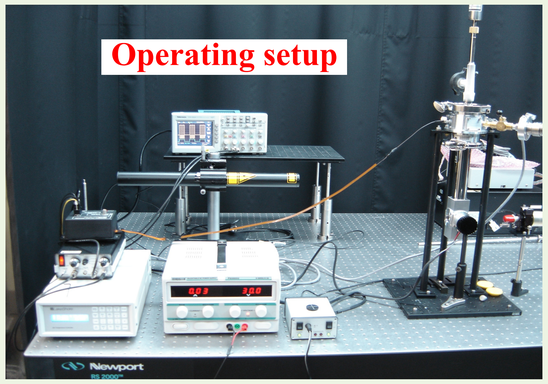
1. **LN2-P-FPQCL-430** ---- generates the cryogenic temperature pulsed multimode emission centered at 430 cm^{-1} or 23.25 µm with average power < 1 mW @ 80 K. The divergence of output beam: far field elliptical (FWHM), vertical 60°, and horizontal 40°
2. **TPG pulser** ---- timing pulse generator
   Pulse duration: 0 ~ 200 ns, Pulse period: 200 ns ~ 105.1 µs
3. **LDD QCL driver** ---- pulser switching unit

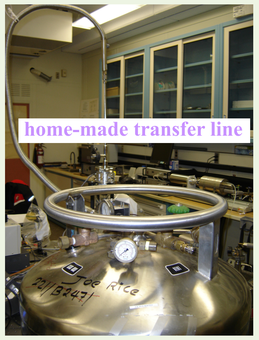
Up to 30 A, 60 V (DC), Rep rate 1MHz, controlled by TPG, and power by DC PS

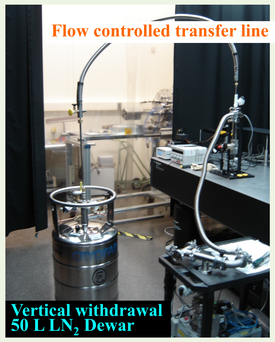
4. **High-precision DC adjustable power supply**

Output voltage: 0 ~ 50 V, Output current: 0 ~ 5A

Operation of QCL at 23 µm







Cryostat system: Pump down to 2 × 10^{-6} Torr, lower the pressure of LN_2 container, flow through LN_2 to cool down around 77.5 K to 78 K using flow controlled transfer line.

23 µm QCL system: Beware of the polarity of the laser. Powered with negative bias on the laser contact and positive bias on the base contact. The connection between the laser and pulse switching unit is floating. It must not be connected with the ground.

TPG pulser - pulse width: 100 ns with the period of 10 µs, duty cycle: 1 %

High-precision DC adjustable power supply

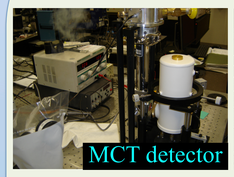
Adjust DC voltage, current drawn 10 mA @ 1 V, 40 mA @ 30 V

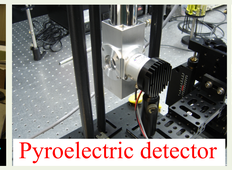
Detection: Pyroelectric detector, HgCdTe (MCT) detector

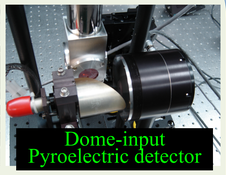
Apply the gate signal with a frequency of 10.5 Hz generated by a lock-in amplifier over the 100 kHz pulses from TPG to use a pyroelectric detector

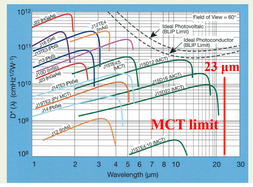
Test method for QCL at 23 µm

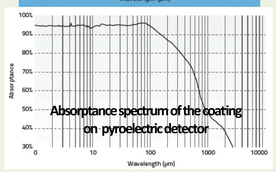
Selection of detector



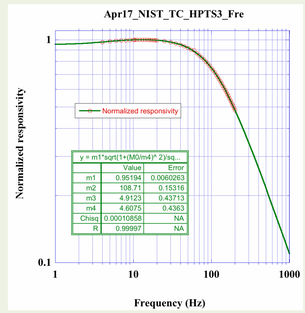




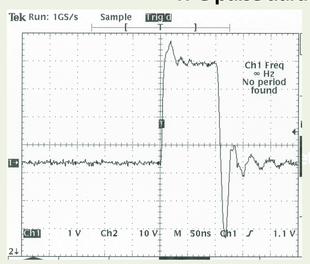


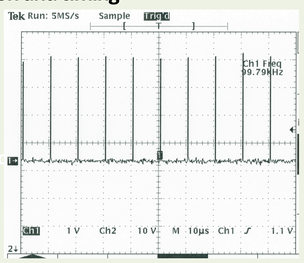


Frequency dependence of pyro detector

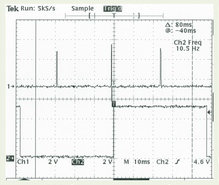


TPG pulse duration and timing

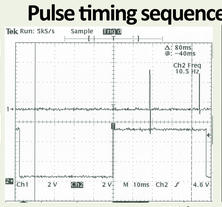


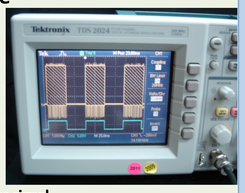


Pulse timing sequence



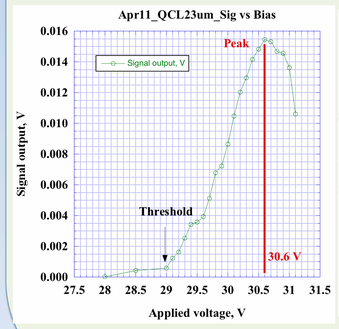
Without gate signal



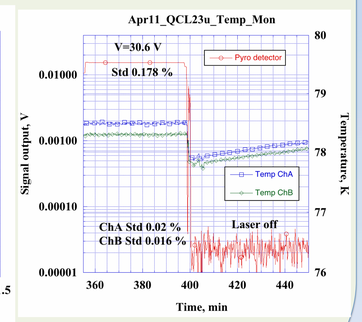


With gate signal

Test results

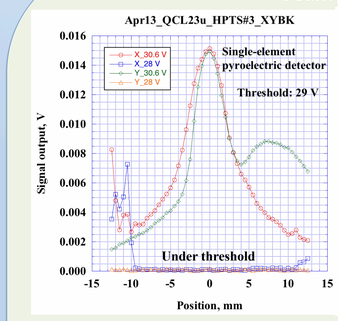


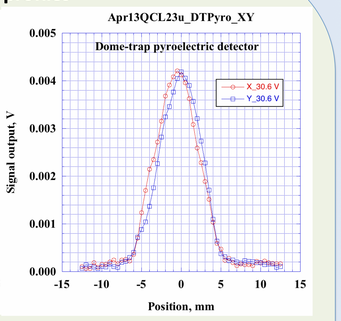
Laser output power vs DC voltage



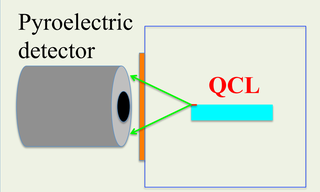
Stability of laser and temperature

Beam profiles



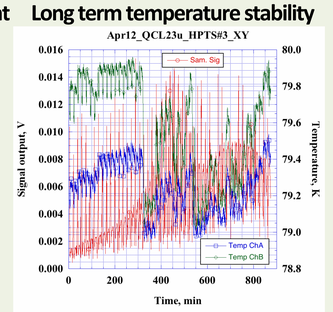


Schematic of spatial measurement

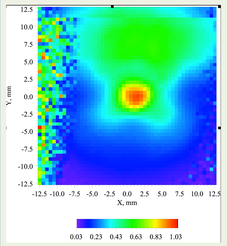


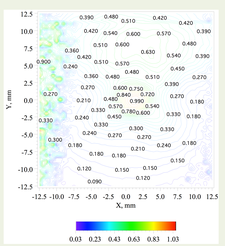
Beam divergence:
vertical 60° and horizontal 40°

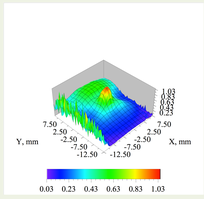
Long term temperature stability



Spatial distribution of beam







Average power assessment

$$Power = \frac{\sum \frac{V_i}{S_d} \Delta S}{\Re}$$

Detector area: 16 mm^2
Power responsivity @1.32 µm: 16985 V/W
P = 20 µW to 30 µW

Conclusions

- A new QCL at 23 µm has been implemented successfully and is operational.
- A special method using gate signal was employed for pyroelectric detectors to complete the preliminary test.
- Dependence of laser output power on voltage, power and temperature stabilities, and beam profiles were characterized.
- The spatial distribution of the beam was useed to assess the average power of the QCL, which is approximately 20 µW to 30 µW.

Future Plans

- Use focusing optics such as KRS5 lens or parabolic gold mirrors optimize the beam
- Wavelength measurement of the QCL laser at 23 µm using FTIS.
- Accurate power measurement using Si: Blocked Impurity Band (BIB) detector, or Bolometer
- Integrate the QCL at 23 µm with IDEF, CHILR and ILGR.