The all-solid-state narrowband lidar developed by optical parametric oscillator/amplifier (OPO/OPA) technology for simultaneous detection of the Ca and Ca+ layers

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An all-solid-state narrowband lidar system for simultaneous detection of Ca and Ca+ layers has been established in Yanqing Station (40.41° N, 116.01° E). The uniqueness of this lidar lies in the transmitter based on the optical parametric oscillation and optical parametric amplification techniques.

The injection seeded optical parametric oscillator (OPO) and the optical parametric amplifier (OPA) are pumped by the second harmonic of a commercial injection-seeded Nd:YAG laser. It can generate the wavelength is 786 nm or 846 nm laser. Then through the frequency multiplier, the output of 393 nm or 423 nm. The detection laser pulse energies up to 30 mJ at these two wavelengths with a bandwidth smaller than 200 MHz.
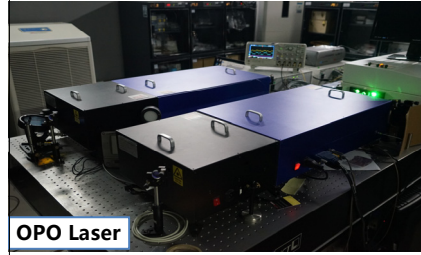
The OPO lidar has good signal-to-noise ratio, and phenomena never seen before have been found from this lidar dataset.
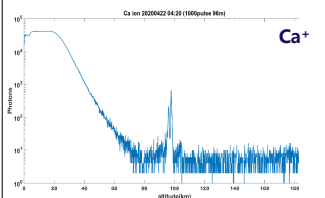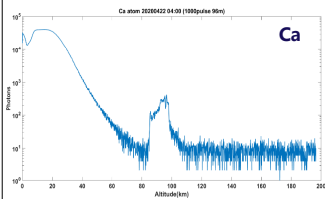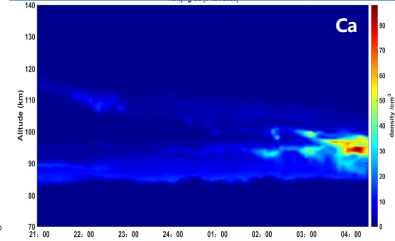
Lidar structure
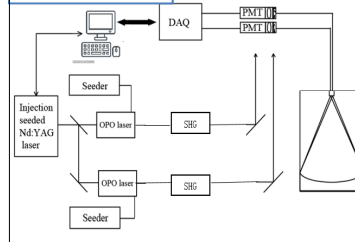
Lidar parameters	Ca	Ca+
Pulse energy (mJ)	31	30
Repetition rate (Hz)	15	15
Linewidth (MHz)	169	154
divergence (mrad)	0.5	0.5

OPO Laser

1.2m telescope

Original lidar photon profile (1min , 100m)

Ca

Ca+

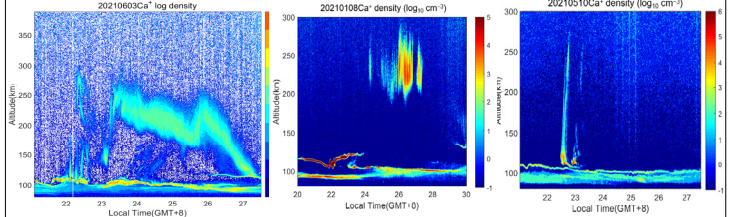

Ca atoms density nightly variation

Ca

Ca+ ions density nightly variation

Ca
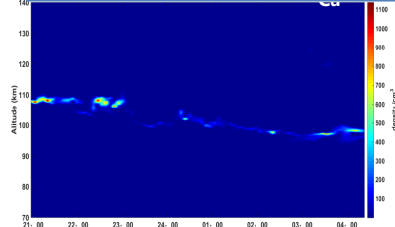


Special phenomena found from lidar dataset

1, Ca+ layer in the region 200 -300km

● The highly-localized phenomena of Ca+ uplifting from E-region to ~300 km could be joint effects of the thermospheric southward wind and the electric fields generated within spread F.

● This study reveals that lidar observations can serve as an important approach to improve our understanding of the ionosphere from a new perspective.

2, Background Ca+ layer

● In the previous lidar reports, Ca+ layer was present as a sporadic layer. Permanent Ca+ layer present was ignored.

● This is because the density of the background Ca+ layer is small, often remains below the lidar detection limit of 5-10 ions cm⁻³

● But background Ca+ layer is detected by OPO lidar at Yangqing
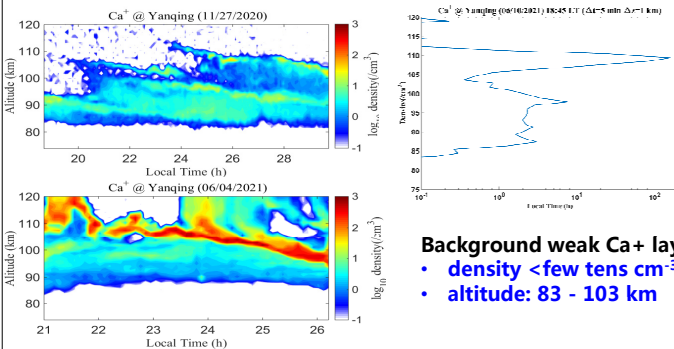
Background weak Ca+ layer
- density <few tens cm⁻³
- altitude: 83 - 103 km

3, Sporadic Ca+ layer below 90km

➢ (Gerding et al 2001), reported 99 sporadic Ca+ layers in Germany, by only had one Ca+ layer been observed below 90 km.

➢ (Alpers et al.,1996): Sporadic Ca+ layers occured frequently in the altitude range 90- 120 km.

But 64 sporadic Ca+ layers reach below 90 km, were found from 131 nights
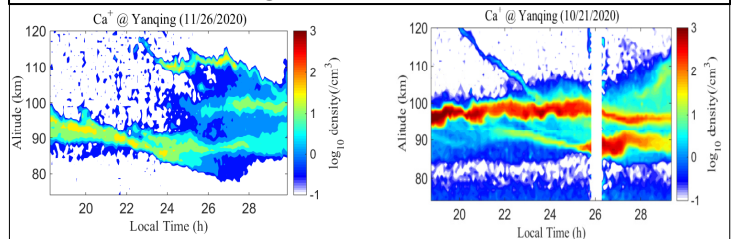
Ca+ layer transported downward from high altitude

Ca+ increases suddenly below 90 km