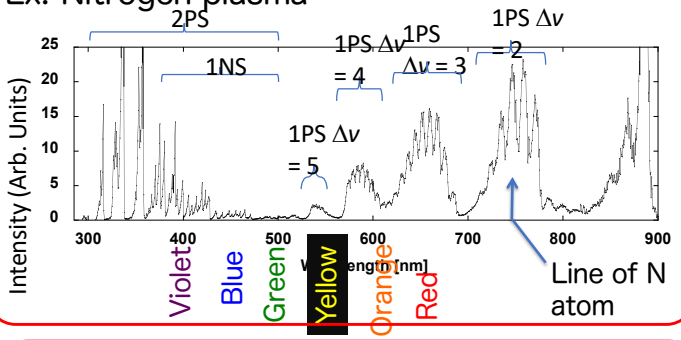
Plasma Chemistry 2 — Molecular Spectroscopy

N_2, O_2, NO, CO, H_2, OH, etc. — to understand thermal structure and reactive radical density

Process application of molecular plasmas

Gas temperature or radical densities are essential

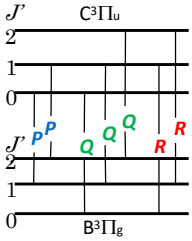
Ex: Nitrogen plasma

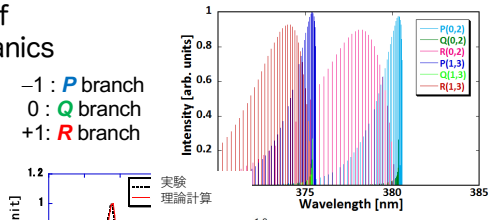


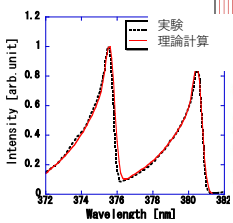
Calculation of N_2 2PS spectrum — vibrational / rotational distribution of N_2

Selection rule of quantum mechanics

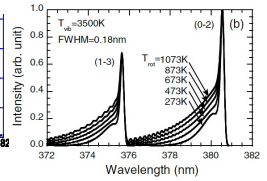
$\Delta J = J' - J'' = \begin{cases} -1 : P \text{ branch} \\ 0 : Q \text{ branch} \\ +1 : R \text{ branch} \end{cases}$







T. Sakamoto, H. Matsuura, and H. Akatsuka, JJAP **45** (2006) 7905



S. Nunomura, M. Kondo, and H. Akatsuka, Plasma Sources Sci. Technol., **15** (2006) 783.

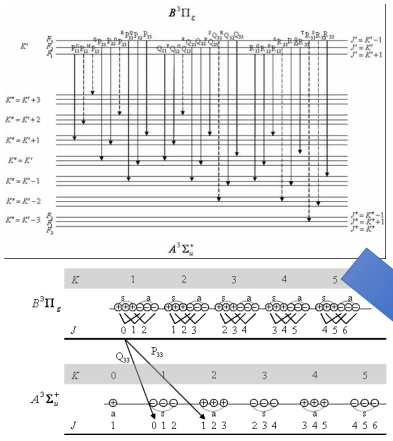
It explains the experiment very well.

Spectral shape is sensitive to changes in gas temperature.

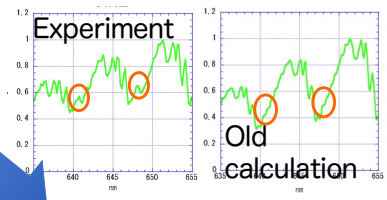
Calculation of N_2 1PS spectrum

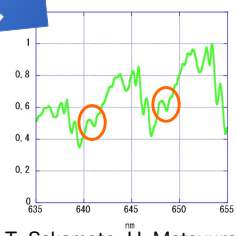
There are 27 transitions that satisfy the selection rule $\Delta J = 0, \pm 1$

- We also included dashed transitions that were not previously included.
- Symmetrical/ antisymmetrical selection rule
- s↔s, a↔a

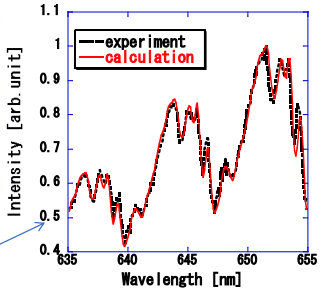


Procedure of N_2 1PS





←Ours



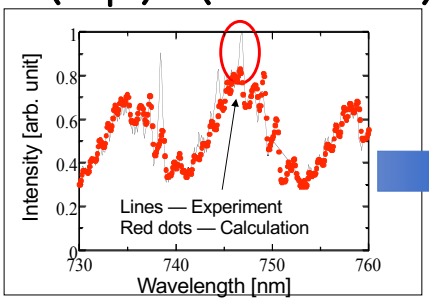
T. Sakamoto, H. Matsuura and H. Akatsuka; *J. Appl. Phys.*, **101**, [2], 023307 (2007).

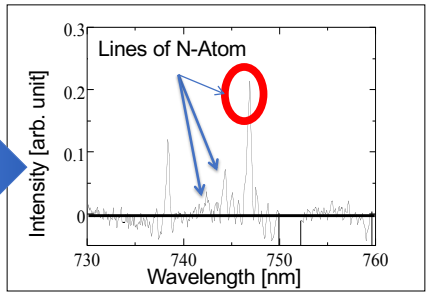
The excellence of our theory is obvious!

T. Sakamoto, H. Matsuura, H. Akatsuka. J. Appl. Phys., **101**, 023307 (2007).

Extracting N-atom lines hidden in N_2 1PS

(Exp.) – (Cal. of 1PS) = N-atom lines





- It became possible to measure the abundance ratio of nitrogen atoms = dissociation degree = with a simple method.
- Attention in material research

Y. Ichikawa, T. Sakamoto, A. Nezu, H. Matsuura and H. Akatsuka; Jpn. J. Appl. Phys., **49**, 106101 (16 pages) (2010).
K. Kuwano et al Jpn. J. Appl. Phys. **55** 086101 (2016).

• Applications

- Process measurement in electronic industry
  - Solar silicon panel production
  - Surface modification
- Automotive engineering
  Engine measurement

Environmental Chemistry, Upper Atmosphere, Planetary Atmospheric Chemistry, …