ご案内

このプレゼンテーションは、

2023年7月9日に行われた

“第4回ライトタッチレーザー国際講演会”で発表された

『世界で初めての新しい歯科Er:YAG

レーザーによる非熱的な殺菌機序』

の研究報告です。

09:40-10:00, Sunday, July 9, 2023

On the production of H_2O_2 in water by LiteTouch Er:YAG-laser irradiation

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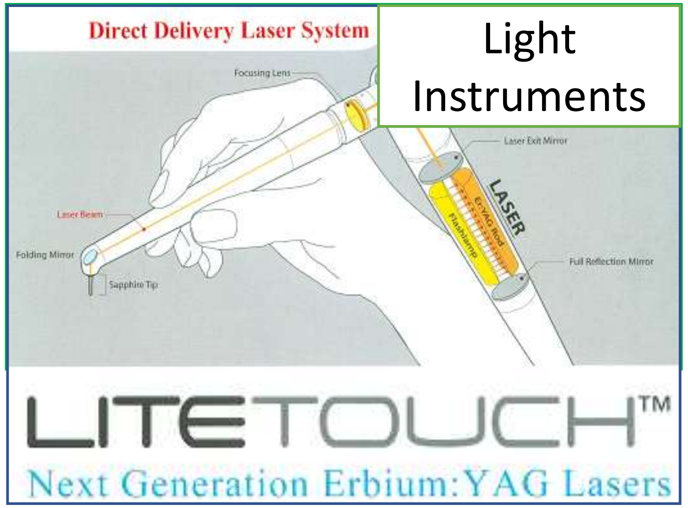
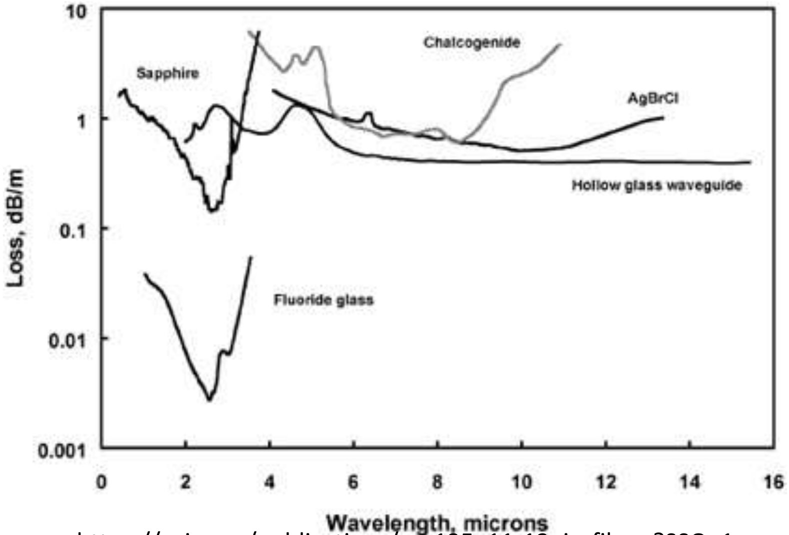
Professor TatsuruShirafuji specializes in plasma research at the Department of Electronics and Informatics, Faculty of Engineering, Osaka Metropolitan University, where he has published many papers. Among them, this underwater plasma theory using a dental laser is attracting attention as an opportunity to construct a new laser bactericidal theory.

Contents

Note: UV-Vis=UltraViolet-Visible Spectroscopy

Reasons for selecting "LITETOUCH" Er:YAG Dental Laser





https://spie.org/publications/pm135_11-13_ir_fibers?SSO=1

Conventional Er:YAG lasers use optical fiber. Laser energy is fairly reduced when laser light pass through the fiber or transmission form with repeated total reflection.

LITETOUCH = Fiber-less! ➡ **Higher Power**

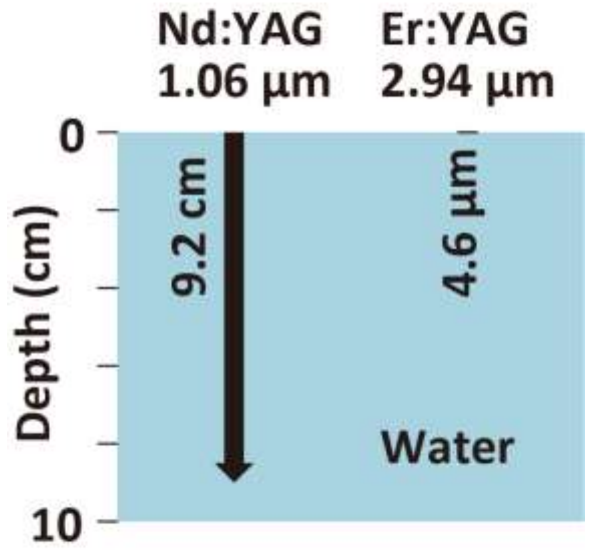
(L.I.H. Laser-in-Handpiece)

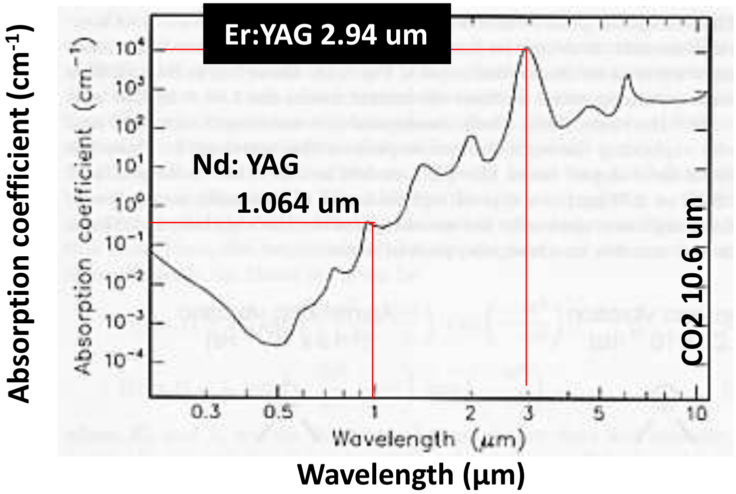
➡ **High Possibility of Plasma**

Minimally Invasive Dentistry (MID) by Er:YAG Laser No.1 "Shallow Penetration Depth"

Nd:YAGは深部の正常組織にまで影響

Er:YAGは表層部の患部だけに影響





Nd:YAG λ = 1.06 µm, α = 1 cm^{-1}

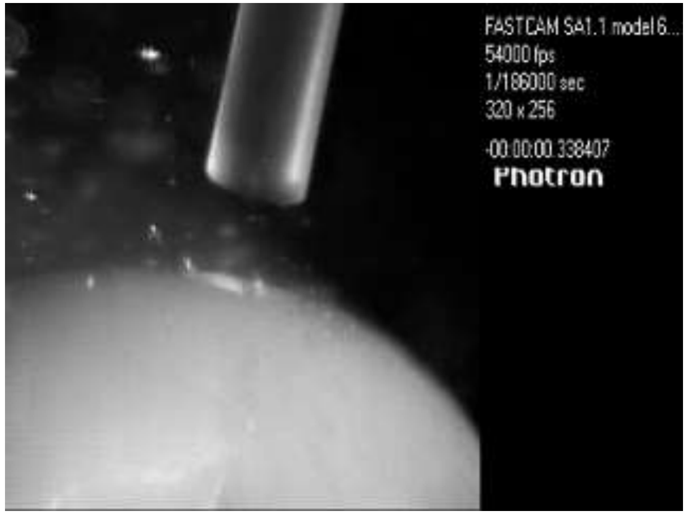
Depth for 1/100 = 9.2 cm

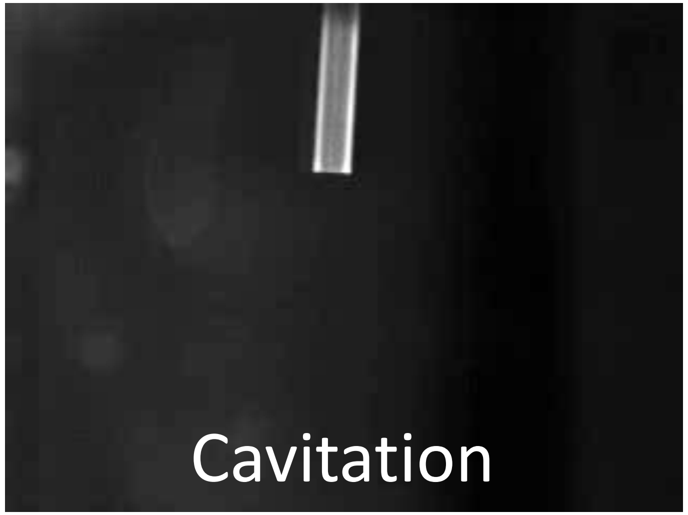
Er:YAG λ = 2.94 µm, α = 10^4 cm^{-1}

Depth for 1/100 = 4.6 µm

Er:YAG is less invasive!

Minimally Invasive Dentistry (MID) by Er:YAG Laser No.2 “Non-Thermal Dentistry”




Cavitation

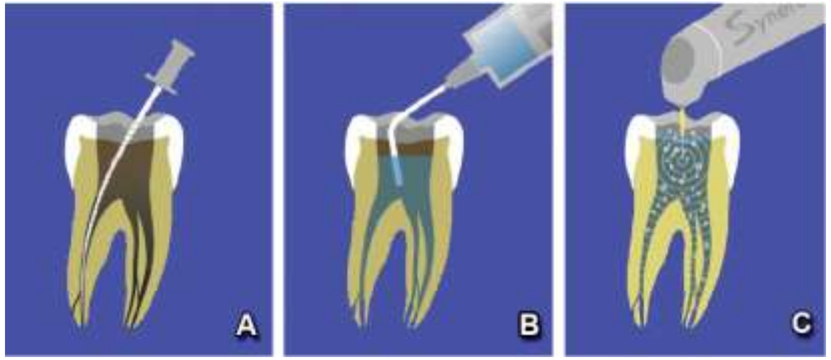
Er:YAG is efficient!   Why?

Large optical absorption coefficient (10^4 cm^{-1}) for water.

➔ Laser energy can be concentrated in extremely limited areas in water.

➔ Cut by Explosive Bubbles = Non-Thermal Dentistry

Minimally Invasive Dentistry (MID) by Er:YAG Laser No.3 “Conventioanl Disinfection”



https://www.dentistrytoday.com/laser-endodontic-debridement-and-canal-disinfection/

Irrigation

L.W.M. van der Sluis, B. Verhaagen, R. Macedo, and M. Versluis:
The role of irrigation in endodontics,
in: Lasers in Endodontics,
eds. G. Olivi, R. De Moor, and E. DiVito
(Springer, 2016) p. 60 and p. 64.

Expected Effect = Root Canal Disinfection

How? = Just Irrigate it with a laser

or

“Removal” rather than “Killing”?

There are not many discussions based on a chemical point of view

Our Previous Results
Bactericidal Effects of Er:YAG Laser Irradiation

Why?

Strepococcus mutans concentration

Control only water — Er:YAG **LiteTouch** — Conventional (Drill)

LiteTouch Er:YAG laser irradiation on caries causes significant reduction of Streptococcus mutans concentration.

This cannot be explained by irrigation only because the target was the open surface of caries (not root canal).

➔ Investigation of chemical aspects of LiteTouch Er:YAG Laser Dentistry

J. Ueda, T. Shirafuji, H. Kambayashi, K. Takahashi, and T. Goto: On the possibility of plasma generation in water using Er:YAG laser and its application to non-invasive bactericidal, 30th Symposium on Plasma Processing (SPP-30), Actcity Hamamatsu, Seminar & Exchange Center, January 21-23, 2013, P2-36, pp. 289-290.

Chemistry of Er:YAG Laser Irradiation in or on Water

References = Sonochemistry
参考分野＝ソノケミストリー（超音波化学）

Bubble Collapse
バブル崩壊（圧壊）

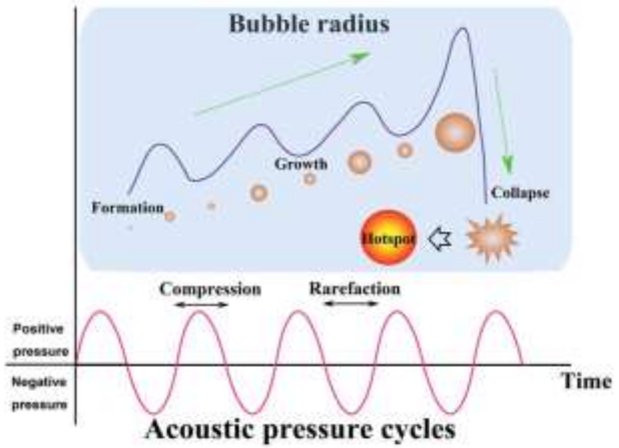


Fig. 2 Schematic illustration of the hotspot formation under acoustic cavitation.

As a result H2O is decomposed to H+OH

$H_2O \rightarrow H + OH$

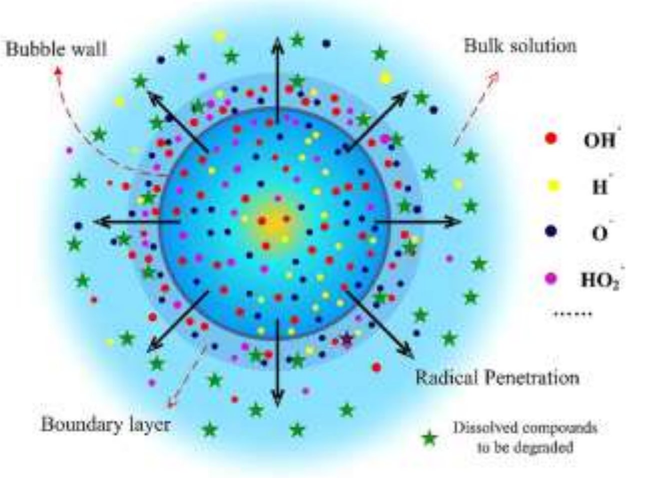
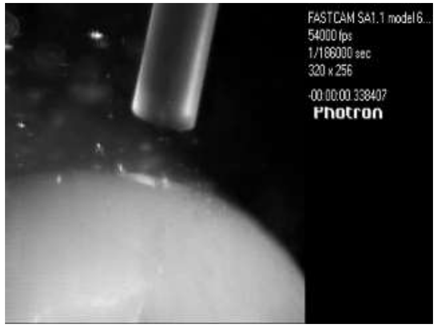


Fig. 1. Schematic of dispersion of free radicals from the cavitation bubble to the surrounding liquid.

The same phenomenon is also expected for Er:YAG

Er:YAGの場合にも同じ現象が期待される



Z. Li, J. Dong, L. Wang, Y. Zhang, T. Zhuang, H. Wang, X. Cui, and Z. Wang: A power-triggered preparation strategy of nano-structured inorganics: sonosynthesis, Nanoscale Adv. 3, 2423 (2021).

K. Peng, S. Tian, Y. Zhang, Q. He, and Q. Wang: Penetration of hydroxyl radicals in the aqueous phase surrounding a cavitation bubble, Ultrasonics Sonochemistry 91, 106235 (2022).

Experiment
UV-Vis Spectroscopy on Er:YAG-laser-irradiated Water

With UV-Visible Spectrophotometer Analysis of Er:YAG laser irradiated water

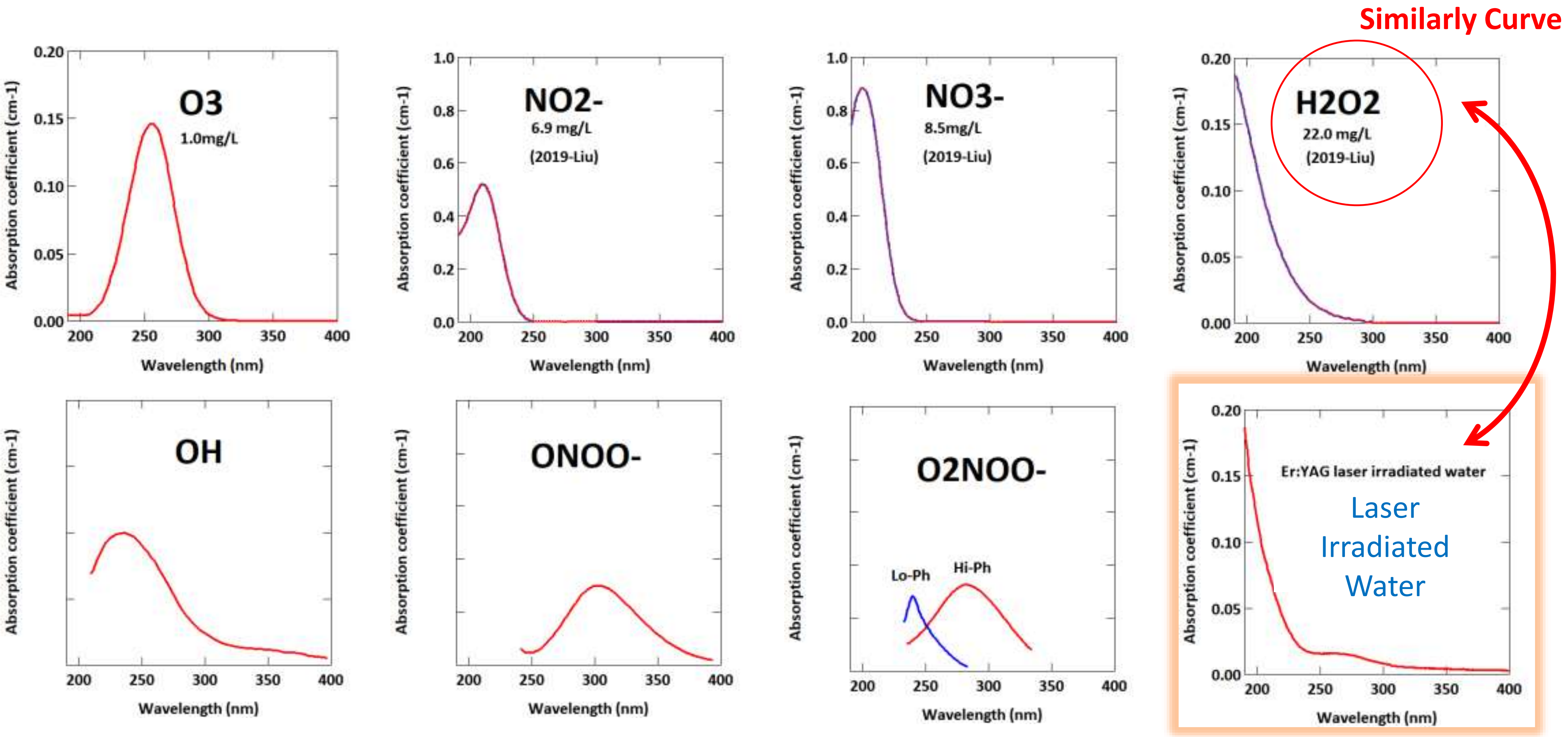
Degree of light absorption in the visible-ultraviolet region Wavelength dependence (spectrum) of wavelength

Quartz cuvette

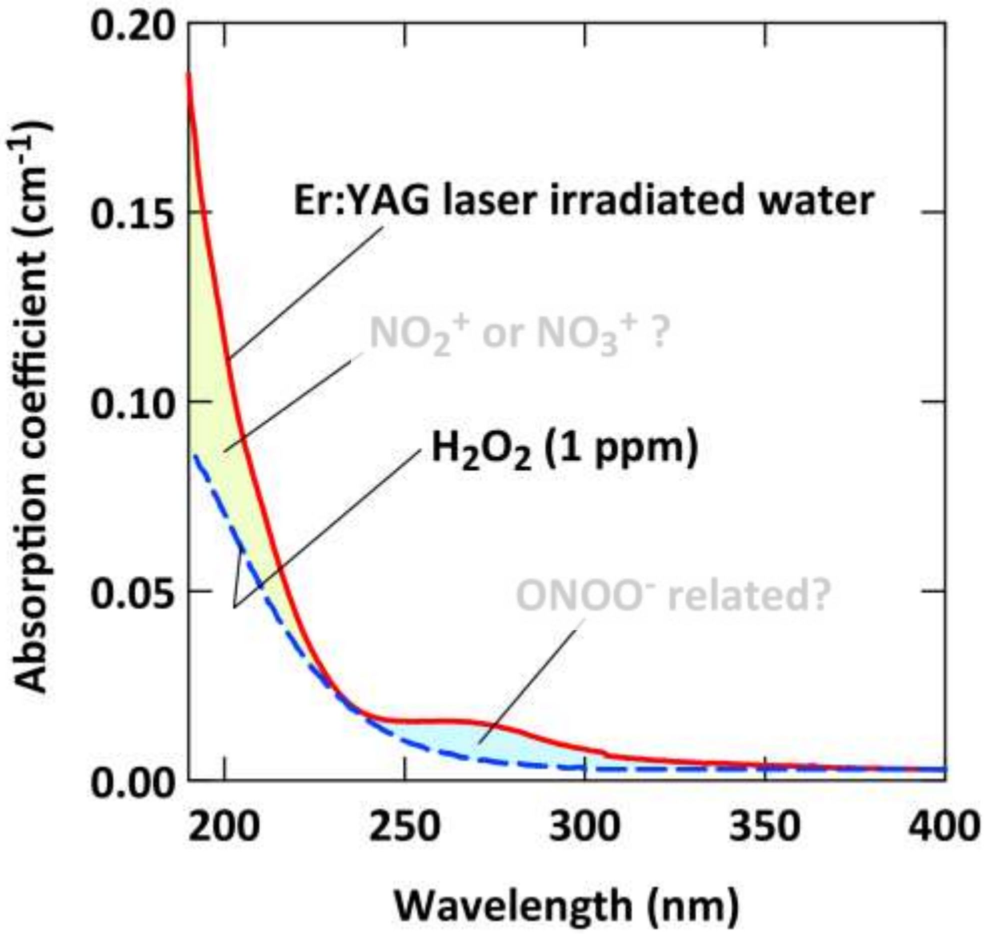
Shimadzu UV-1900
UV-Vis Spectrometer

Results

Comparison of UV absorption curves of molecules



Analysis
Focusing on H2O2



The experimental result is governed by H2O2.

H2O2 concentration is approximately 1 ppm.

Oxidol = 3% H2O2 aqueous solution
Much less than oxidol.
However, the H2O2 concentration in the laser spot is presumed to be locally and instantaneously high.

実験結果は，過酸化水素で概ね説明される．

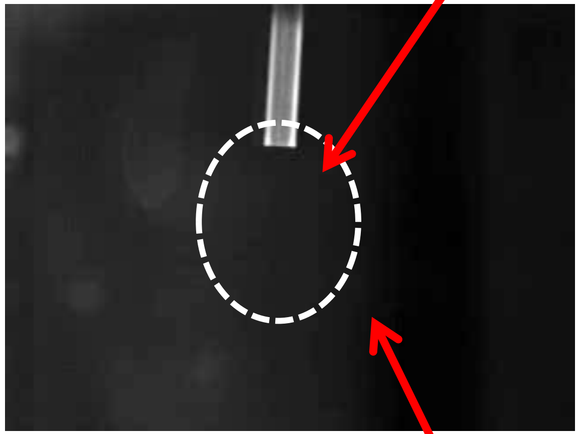
H2O2濃度はおおよそ 1 ppm.

オキシドール = 3% H2O2 水溶液
オキシドールより極めて薄い．
しかし，レーザースポットでは
局所的・瞬時的に高濃度と思われる．

Possible Mechanism of H_2O_2 Production

$H_2O \rightarrow H + OH$

Cavitation Bubble



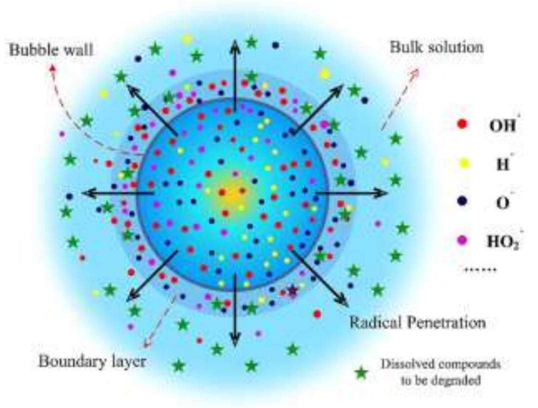


Fig. 1. Schematic of dispersion of free radicals from the cavitation bubble to the surrounding liquid.

$OH + OH \rightarrow H_2O_2$

Collapse of cavitation bubbles causes

H2O → H + OH

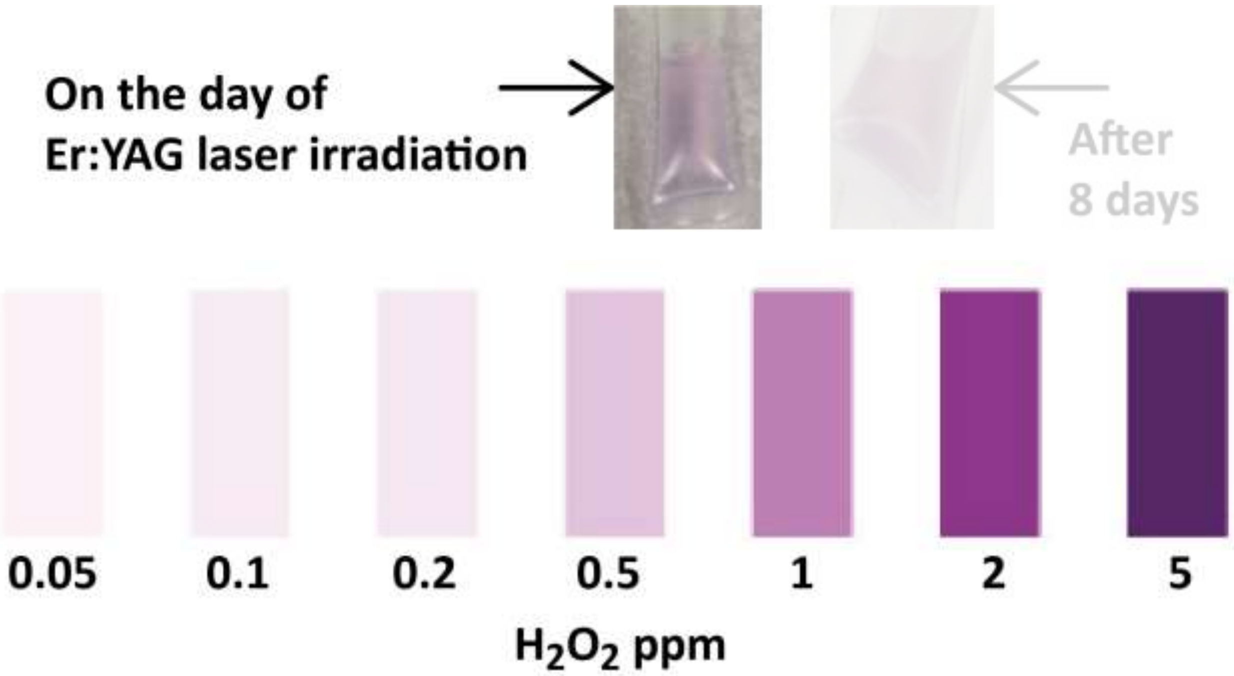
After the collapse of the bubbles

OH + OH → H2O2

Crosscheck
(Our Previous Results)

Evaluated H2O2 concentration does not match exactly to that deduced from UV-Vis results, but they are in the same order of magnitude.

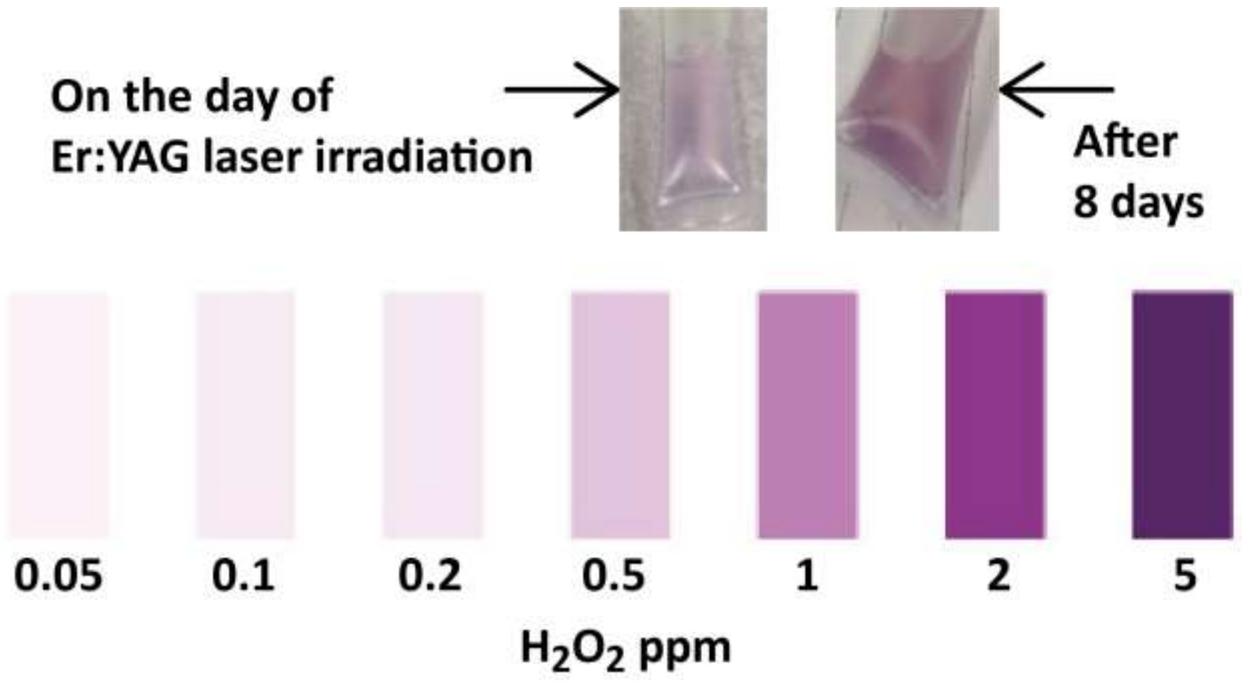
評価された H2O2 濃度は，UV-Vis の結果から推定された濃度と正確には一致しないが，同じオーダーである．



共立理化学研究所

PACKTEST WAK-H2O2
(Kyoritsu Chemical-Check Lab., Corp.)

An Interesting Result



The color of the pack test sample darkened after 8 days.

パックテストサンプルの色が
８日後に濃くなった.

But　しかし

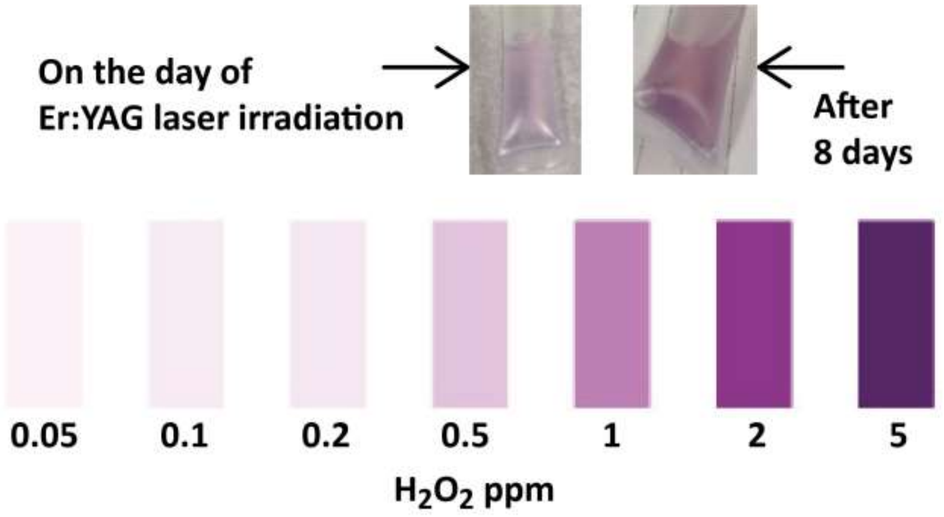
OH + OH → H2O2

This reaction is very fast.

Cannot explain our result.

この反応は，きわめて速い.
我々の結果を説明できない.

A Possible Mechanism



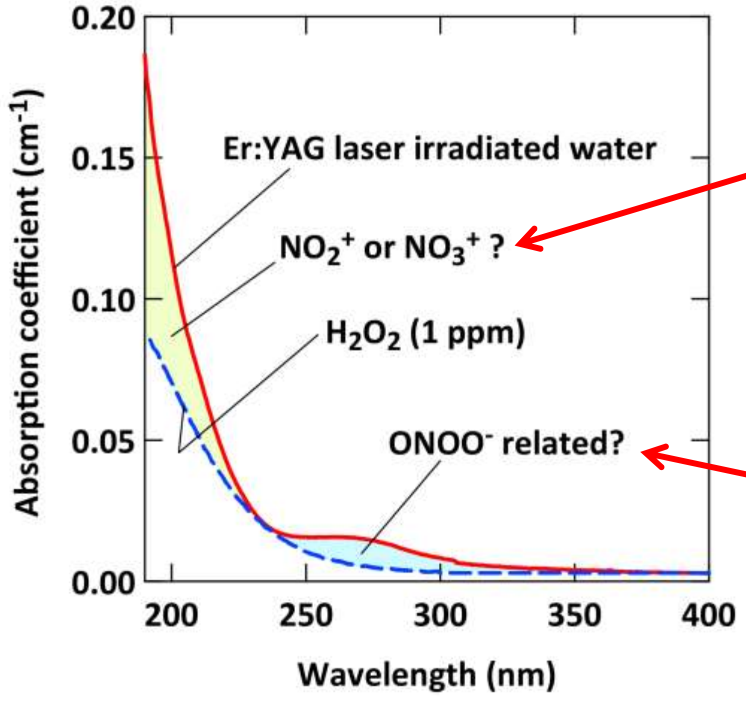
This suggests that some post-irradiation reactions continue to produce OH radicals.

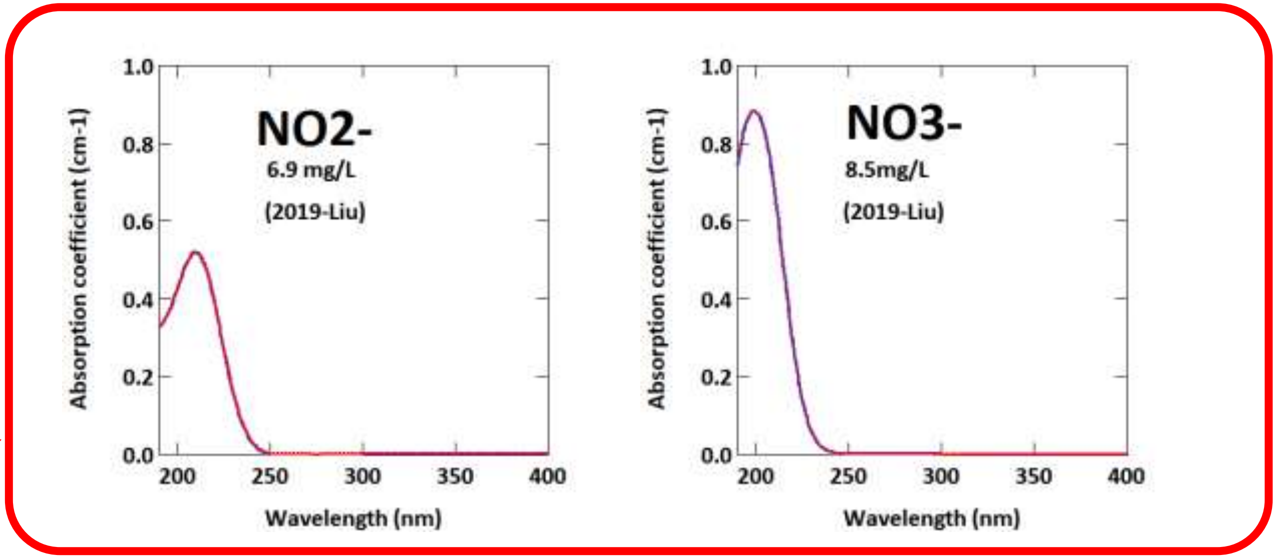
In other words, this fact is a phenomenon that demonstrates the persistence of the bactericidal action.

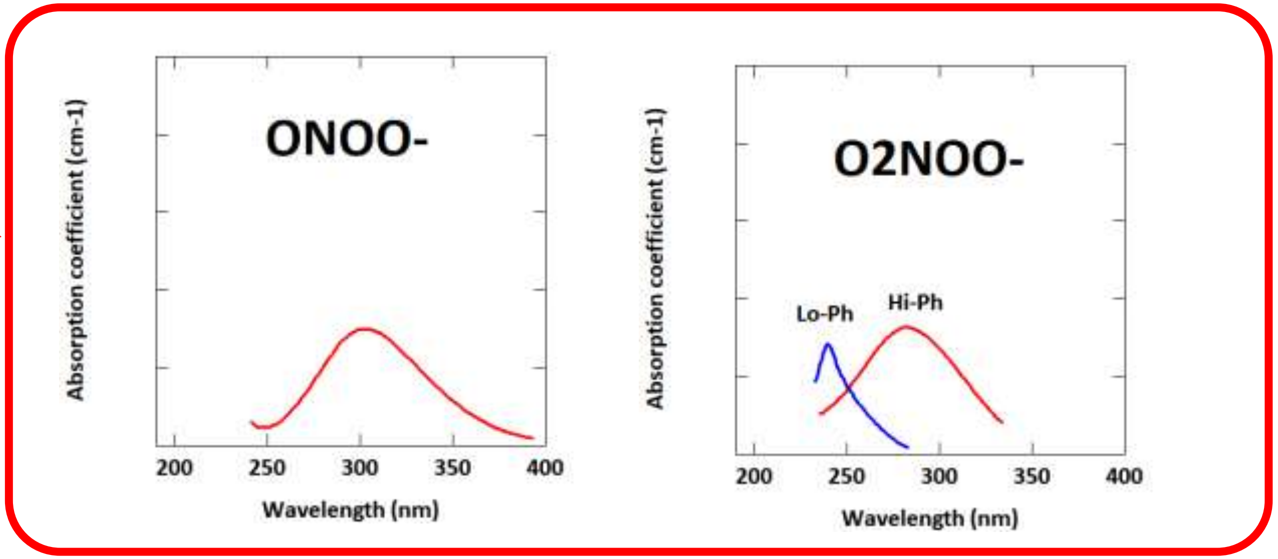
H_2O_2 Sustained and Increased in the PackTest for 8 days

Analysis
Focusing on the deviation from H2O2

The deviation from H2O2 spectra

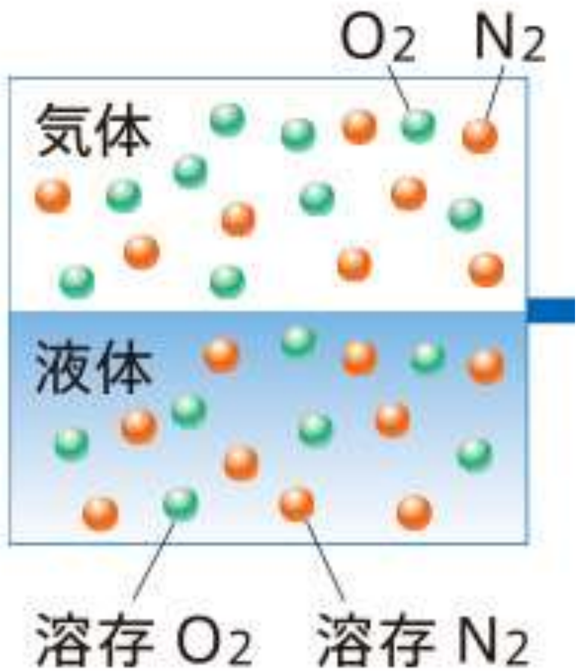






Where does Nitrogen come from?

窒素はどこからくる？



Gases

liquids

Melted O2 Melted N2

https://www.separel.com/technology/

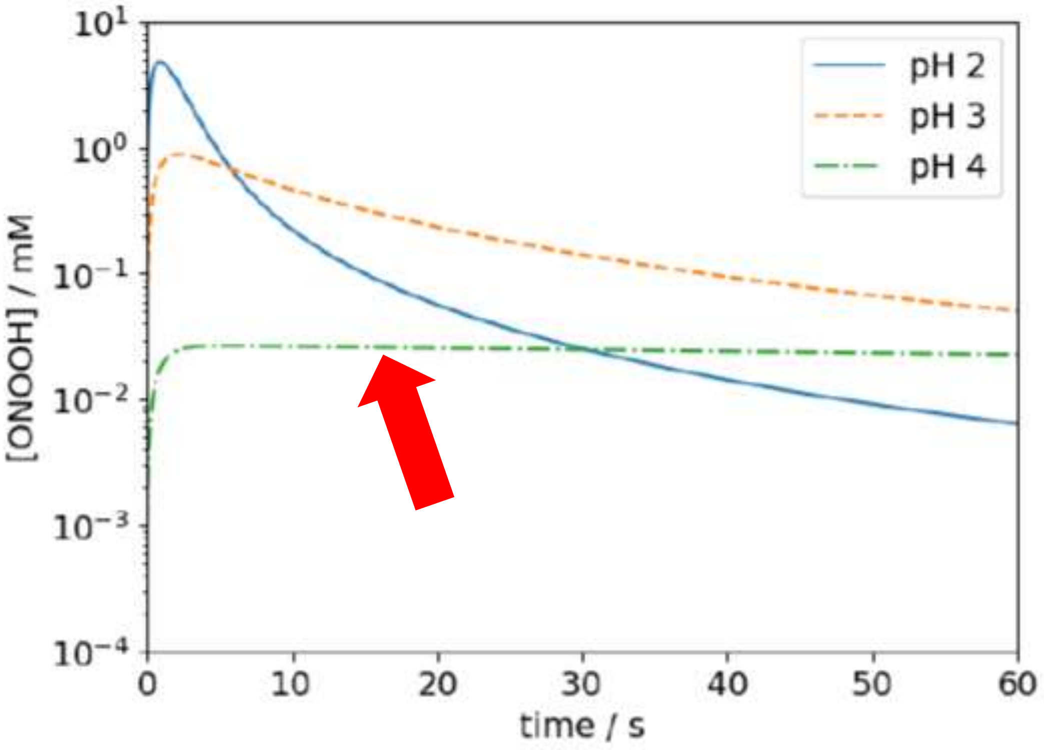
Air is dissolved in water.

空気は水に溶けている.

Air is 20%O2 + 80%N2 + others.

空気は 20%O2 + 80%N2 + その他

A Possible Mechanism
Focusing on ONOOH/ONOO-



M. Balazinski, A. Schmidt-Bleker, J. Winter, and T. von Woedtke: Peroxynitrous acid generated in situ from acidified H2O2 and NaNO2. A Suitable novel antimicrobial agent?, Antibiotics 10, 1003 (2021).

ONOOH ⇔ $ONOO^-$ + H^+

Equilibrium = Long-Life

平衡 = 長寿命

ONOOH → NO_2 + OH (30%)

ONOOH → NO_3^- + H^+ (70%)

OH radicals are produced during gradual consumption of ONOOH

ONOOHが徐々に消費されるときに，一部がOHラジカルとなる

Summary

1.Er:YAG laser irradiation on water induces H2O2.

2.This might be one of the causes of bactericidal effects.

3.Our results suggest possibility of post-irradiation production of OH, which may be related to the formation of peroxynitric acid (ONOOH).