ANGEL´s
Pre-conference Tutorial

Stephan Barcikowski,
Vincenzo Amendola,
Friedrich Waag

Outline

9:45: Optimal laser and processing strategies for ablation, fragmentation, and melting (Barcikowski)

11:15: Unique nanoparticle properties and functionalities accessible by laser synthesis and processing of colloids (Amendola)

12:45: Lunch break and preparation for Science Slam (with brief Tips and Tricks from Friedrich Waag)

13:45: Science Slam (2 min oral pitch talk from each student) (Waag)

14:45: Practical course and demonstration of automated laser synthesis (Waag)

16:15: Discussion: Matching study design with unique goals of the project (Amendola, Barcikowski, Waag)

16:45: Wrap-up, flashback-round

17:30: Participants move to the ANGEL Welcome Reception (The Dome Room of the UVA Rotunda)

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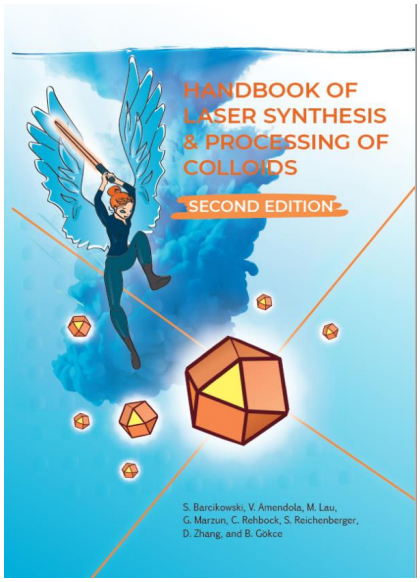
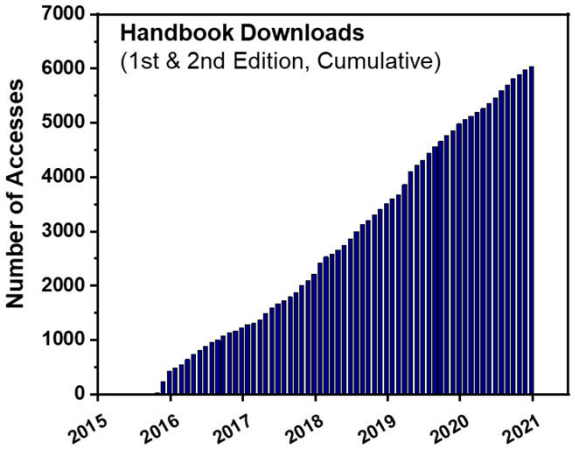
Laser and Processing Strategies for Ablation, Fragmentation, and Melting

Stephan Barcikowski

Open Access: Handbook of Laser Synthesis and Processing





Barcikowski, S.; Amendola, V.; Lau, M.; Marzun, G.; Rehbock, C.; Reichenberger, S.; Zhang, D.; Gökce, B.: *Handbook of Laser Synthesis and Processing of Colloids (2nd Edition)*. DuEPublico (2019), 1-202

Open Access: https://doi.org/10.17185/duepublico/70584

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Review Article: The „Compendium“

CHEMICAL REVIEWS
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Laser Synthesis and Processing of Colloids: Fundamentals and Applications

Dongshi Zhang, Bilal Gökce, and Stephan Barcikowski*

Technical Chemistry I and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Universitaetsstrasse 7, 45141 Essen, Germany

CONTENTS

Received: July 19, 2016
Published: February 13, 2017

D. Zhang, B. Gökce, S. Barcikowski. Laser Synthesis and Processing of Coloids: Fundamentals and Applications. **Chem Rev. (2016)**

Review Article: The „Update“ on Metal Oxides

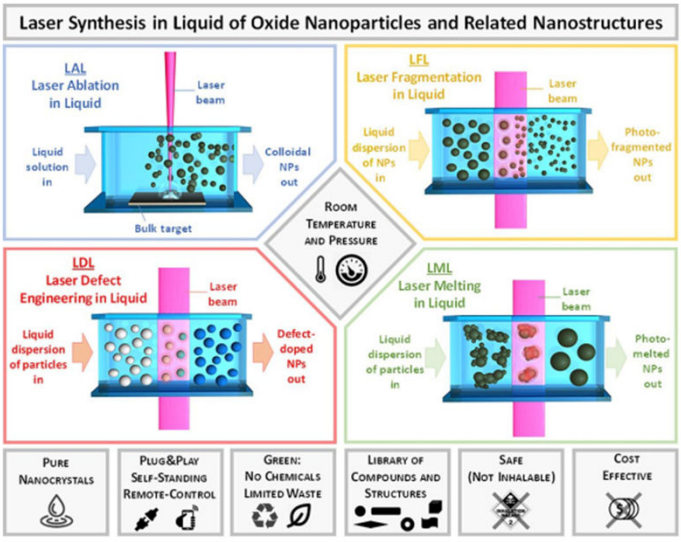
Chemistry
A European Journal
Chemistry Europe
European Chemical Societies Publishing

Review | Open Access

Room-Temperature Laser Synthesis in Liquid of Oxide, Metal-Oxide Core-Shells, and Doped Oxide Nanoparticles

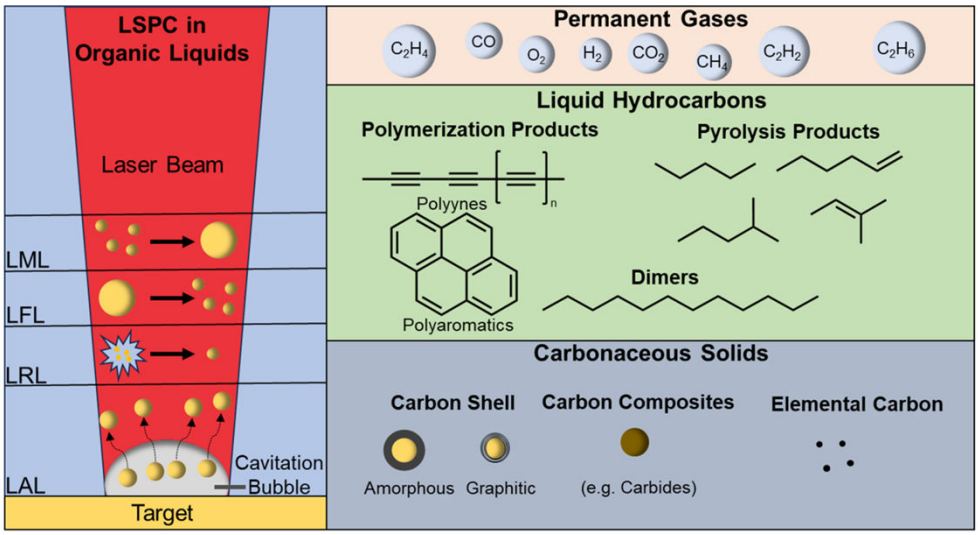
Dr. Vincenzo Amendola, Dr.-Ing. David Amans, Dr. Yoshie Ishikawa, Dr. Naoto Koshizaki, Dr. Salvatore Scirè, Dr. Giuseppe Compagnini, Dr. Sven Reichenberger, Dr.-Ing. Stephan Barcikowski ... See fewer authors

First published: 20 April 2020 | https://doi.org/10.1002/chem.202000686 | Citations: 190



V. Amendola, D. Amans, Y. Ishikawa, N. Koshizaki, S. Scirè, G. Compagnini, S. Reichenberger, S. Barcikowski, *Chem. - A Eur. J.* **2020**

Review Article: Organic Liquids



T. Fromme, S. Reichenberger, K. M. Tibbetts,, S. Barcikwoski. Beilstein J. Nanotechnol. **2024**

Laser and Processing Strategies

to Create and Modify Colloids

Stephan Barcikowski

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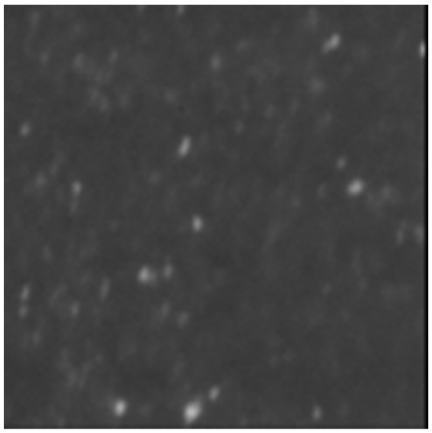
Colloids Move around

Robert Brown (1827)

Random movement of pollen and mineral debris in water
Brownian “molecular” dynamics



Movement speed scales with $\sim \frac{1}{r}$

Brownian motion of 20 nm latex spheres in water

Robert Brown: "A brief account of microscopical observations made in the months of June, July and August, 1827, on the particles contained in the pollen of plants; and on the general existence of active molecules in organic and inorganic bodies." In: Philosophical Magazine. 1828

Gold and Light

Michael Faraday (1858)

Shining light at colloidal gold
shows behaviour like “continuum” and “particles” at the same time:

→ Public “bakerian” lecture including synthesis protocol

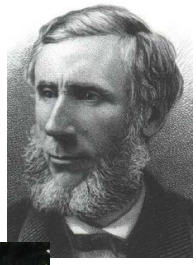
Slide that Faraday used in his lecture on gold sols, in 1858.
[The Whipple Museum]

Faraday's slide, engraved inscription: "Faraday's gold given to me himself after his lecture at the RI".
[The Whipple Museum]

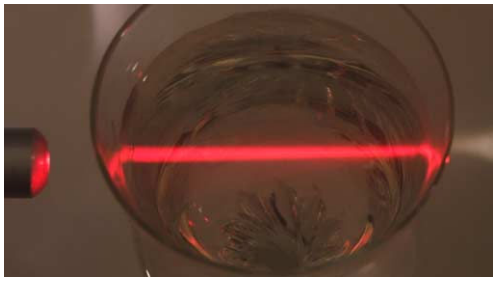
Michael Faraday. “The Bakerian Lecture. —Experimental relations of gold (and other metals) to light”. 1857 https://doi.org/10.1098/rstl.1857.0011

Light Scattering by Particles

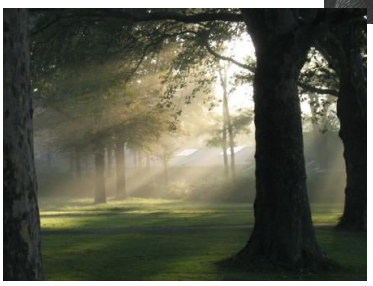
John Tyndall (1856)



Scattering of light at colloidal particles and fine dust in all directions
➔ Light beam becomes visible
➔ Allows concentration measurements



Tyndall scattering of a laser beam by nanoparticles



Tyndall scattering of sun light at dust / moist (aerosol)

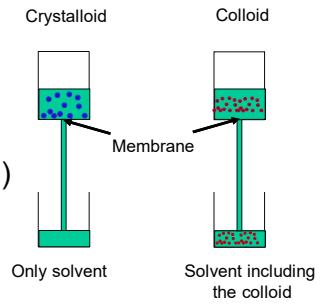
Definition of the Term "Colloid"

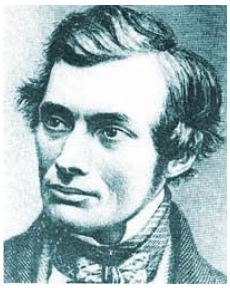
Thomas Graham (1861)

Introduction of the Term „Colloid"

Dialysis of Sols (solids dispersed in liquid) for Classification into

- **Crystalloids** (possible separation by filtration)
- **Colloids** (separation not possible by filtration)





Colloids: solid particles with characteristic sizes of 1 nm to ≈ 1 µm that are finely dispersed in a liquid.

Further Mile Stones in Colloid Chemistry

1827	R. Brown: Observation of the Brownian motion
1856	M. Faraday: Synthesis of colloidal gold nanoparticles J. Tyndall: Scattering of light on micro/nano objects
1861	Th. Graham: Definition of the term Colloid
1890	J. W. Raleigh: Importance of Surfactants
1897	W. Ostwald: Ripening of nanoscaled objects
1905	A. Einstein: Theory of brownian motion
1906	M. Smoluchowski: Theory of brownian motion
1925	R. Zsigmondy: Nobel price for Chemistry (Ultra microskopy)
1926	T. Svedberg: Nobel price for Chemistry (Ultra centrifugation)
1932	I. Langmuir: Nobel price for Chemistry (Surface chemistry)
1941	B. Derjaguin and L. D. Landau
1948	E. J. W. Verwey and Th. Overbeck } DLVO-Theory

Quickie

You direct a laser beam at a 1 cm cuvette containing a nanoparticle colloid. You try a green (532 nm) and a near-infrared (1064 nm) laser beam. How much is the green compared to the near-infrared laser attenuated on its way through the cuvette?

A) Equally negligible, because nanoparticles are too small to scatter light.

B) Same, because the two effects compensate each other: short wavelengths are refracted weaker but scattered more strongly (and vice versa for long wavelengths)

C) The green laser beam suffers 16 times losses in intensity

D) The near-infrared laser beam is attenuated 2 times stronger.

E) I don´t care, need more coffee first

Laser and Processing Strategies

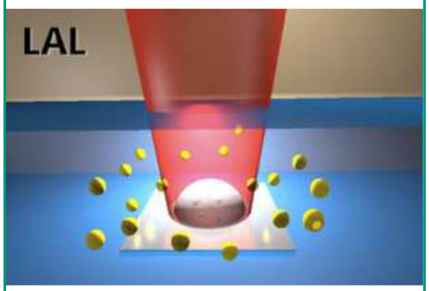
to Create and Modify Colloids

by Ablation, Fragmentation, and Melting

Stephan Barcikowski

Classification of Laser Synthesis and Processing of Colloids

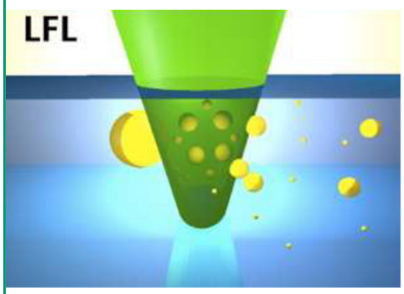
Laser Ablation



Feedstock:
Bulk Solid

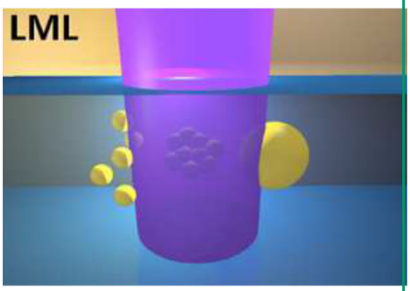
Colloid Synthesis

Laser Fragmentation



Feeedstock:
Micro- or Nanoparticles

Laser Melting



Feedstock:
Aggregates of Nanoparticles

Colloid Processing

D. Zhang, B. Gökce, S. Barcikowski. Chem Rev. (2017)

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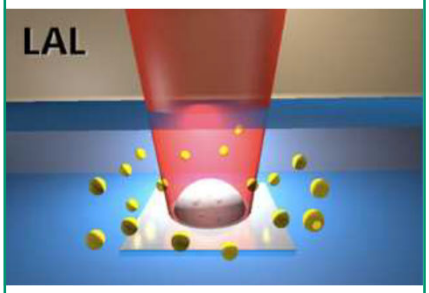
Classification of Laser Synthesis and Processing of Colloids

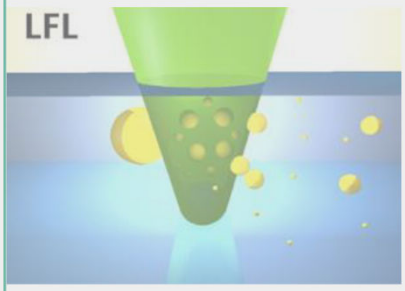
Laser Ablation



Feedstock:
Bulk Solid

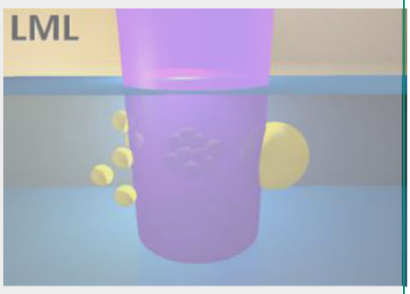
Colloid Synthesis

Laser Fragmentation



Feeedstock:
Micro- or Nanoparticles

Laser Melting



Feedstock:
Aggregates of Nanoparticles

Colloid Processing

D. Zhang, B. Gökce, S. Barcikowski. Chem Rev. (2017)

Laser Ablation in Liquid (LAL, PLAL)

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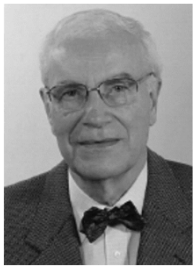
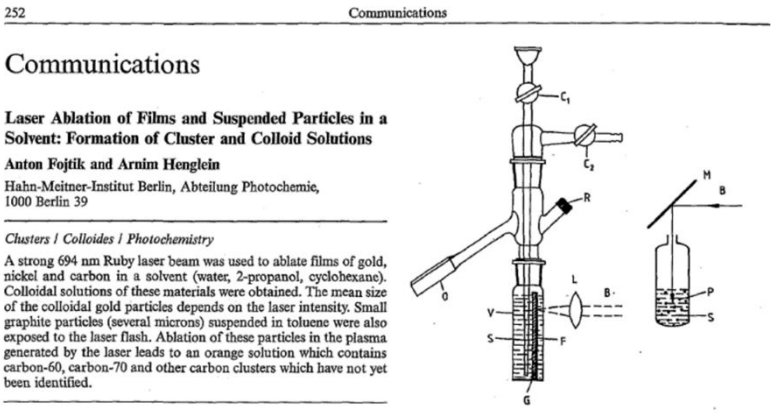
Discovery of Laser Synthesis and Processing of Particles in Liquids

Anton Fojtik



Arnim Henglein, † 2012



252 Communications

Communications

Laser Ablation of Films and Suspended Particles in a Solvent: Formation of Cluster and Colloid Solutions

Anton Fojtik and Arnim Henglein

Hahn-Meitner-Institut Berlin, Abteilung Photochemie, 1000 Berlin 39

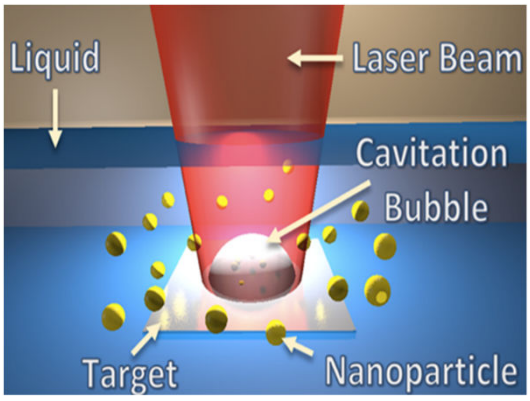
Clusters / Colloides / Photochemistry

A strong 694 nm Ruby laser beam was used to ablate films of gold, nickel and carbon in a solvent (water, 2-propanol, cyclohexane). Colloidal solutions of these materials were obtained. The mean size of the colloidal gold particles depends on the laser intensity. Small graphite particles (several microns) suspended in toluene were also exposed to the laser flash. Ablation of these particles in the plasma generated by the laser leads to an orange solution which contains carbon-60, carbon-70 and other carbon clusters which have not yet been identified.

Ber. Bunsenges. Phys. Chem. 97 (**1993**) 2, 252-254

Pulsed Laser Ablation in Liquids

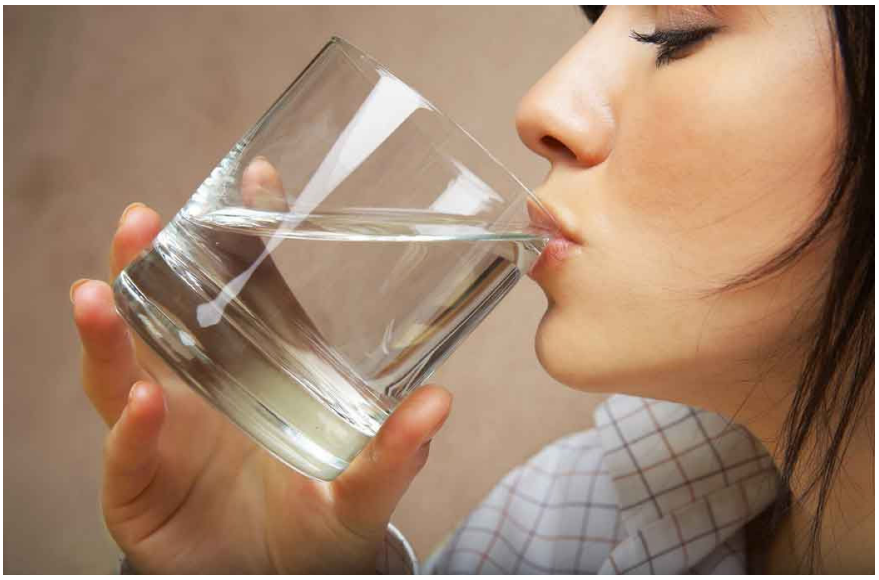
Laser Ablation in Liquids (LAL)



D. Zhang, B. Gökce, S. Barcikowski, *Chem. Rev.*, 117, 5, 2017.

Video Channel: www.youtube.com/nanofunction

Purity Matters.



Purity of "Gold Colloid" (Material Safety Data Sheet)

[redacted]

ProductInformation

Gold Colloid, 5 nm (G1402)
Gold Colloid, 10 nm (G1527)
Gold Colloid, 20 nm (G1652)

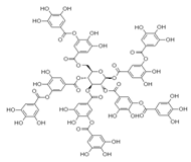
Storage Temperature 2-8 °C

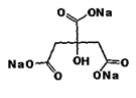
Product Description
Colloidal gold is a discrete, electron dense, non-fading, red colored marker useful as a probe in electron microscopy, light microscopy, and blotting procedures.[1] It requires no additional processing for detection, but in certain applications, the signal can be dramatically enhanced by reaction with silver (Silver Enhancer Kit,

All unconjugated gold colloids contain approximately 0.01% $HAuCl_4$ suspended in 0.01% tannic acid with 0.04% trisodium citrate, 0.26 mM potassium carbonate, and 0.02% sodium azide as a preservative.

Precautions and Disclaimer
Due to the sodium azide content a material safety sheet

All unconjugated gold colloids contain approximately 0.01% $HAuCl_4$ suspended in 0.01% tannic acid with 0.04% trisodium citrate, 0.26 mM potassium carbonate, and 0.02% sodium azide as a preservative.





NaN_3

Quickie

Citrate is an ingridient in soft cheese (and energy drinks). Can´t be too bad to have such an additive in a gold colloid that we not even drink. What do you think?

A) Citrate is just a bad example, often, other, more harmful surfactants are used.

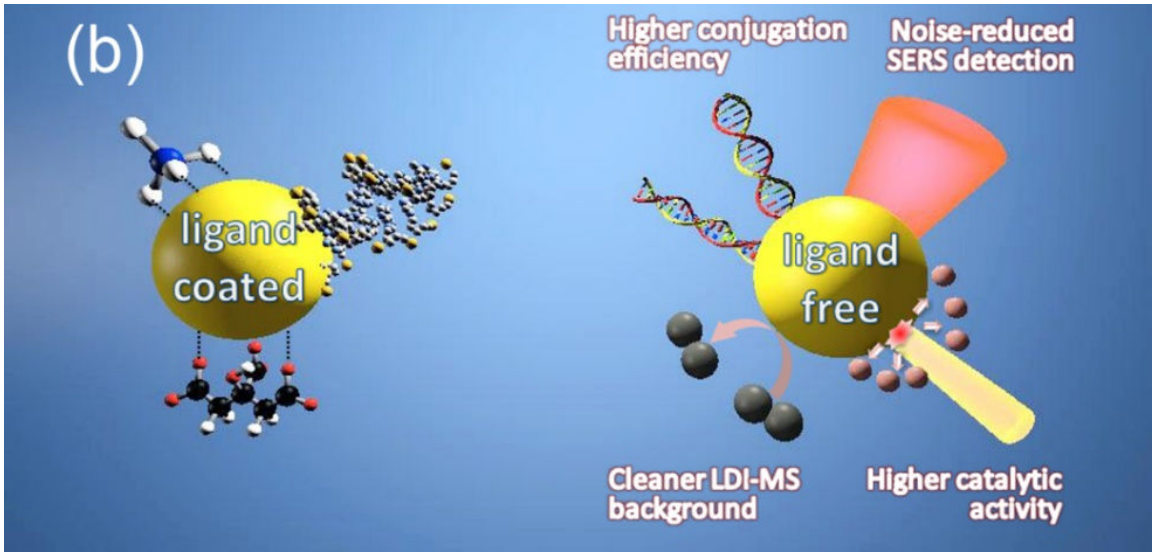
B) Any molecule blocks the nanoparticle surface, suppressing nano-effects

C) Purity makes nanoparticle analytics easier

D) Citrate mainly makes the colloid basic, and stabilizes it electrostatically at the same time

E) Citrate-reduced gold naturally contains a half dozen more critical substances

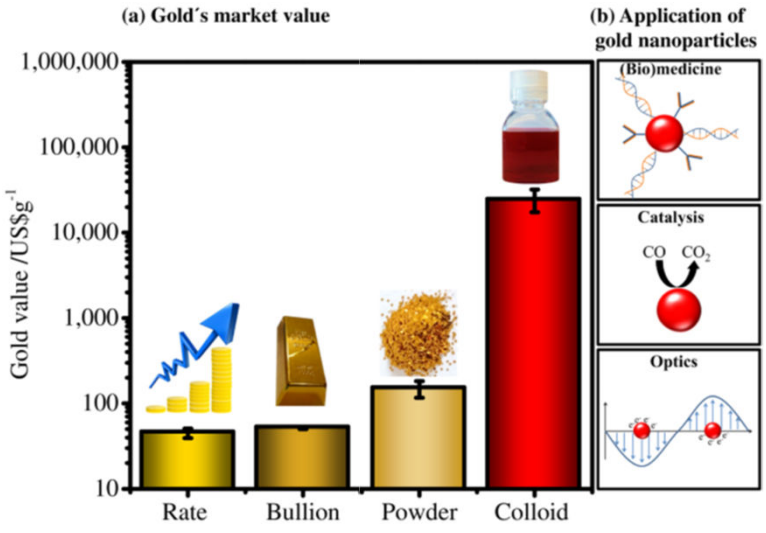
Purity is a Value.



D. Zhang, B. Gökce, S. Barcikowski , Chemical Reviews, (2017)

Upscaling Laser Ablation in Liquid
- Economic (and Ecologic) Motivation -

The Value of Gold



S.Jendrzej, B. Gökce, M Epple, S. Barcikowski. Chem Phys Chem (2017)

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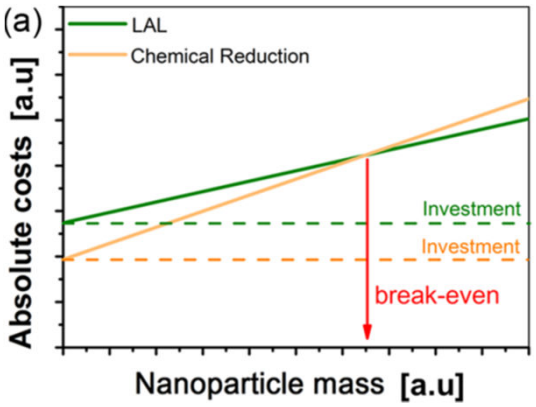
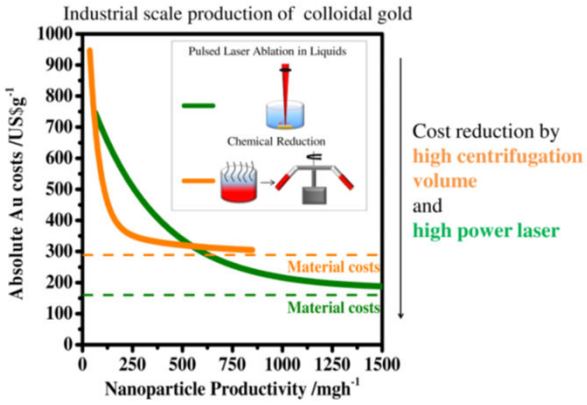
More is better – Think Big!

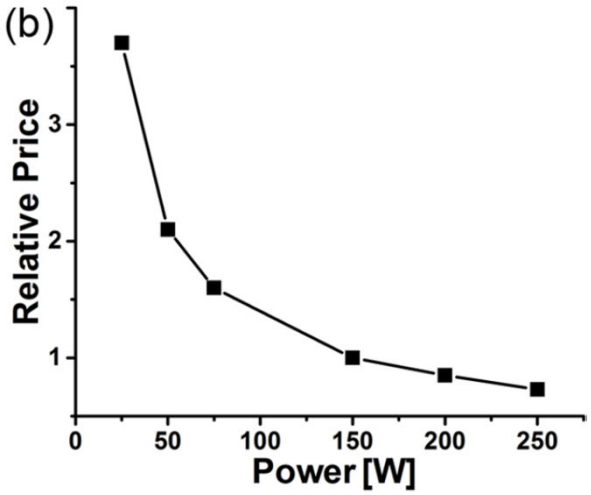


D. Zhang, B. Gökce, S. Barcikowski. Chem Rev. (2017)



S.Jendrzej, B. Gökce, M Epple, S. Barcikowski. Chem Phys Chem (2017)

Laser Power Scaling Law



Keming Du (Edgewave), In: D. Zhang, B. Gökce, S. Barcikowski. Chem Rev. (2017)

Quickie

I understood it´s economic when scaled. But what has this to do with ecology or sustainability?

A) More economic processes are always more ecologic

B) At larger scales, the material and energy ressource savings get even higher, ecologicallybeating wet chemistry

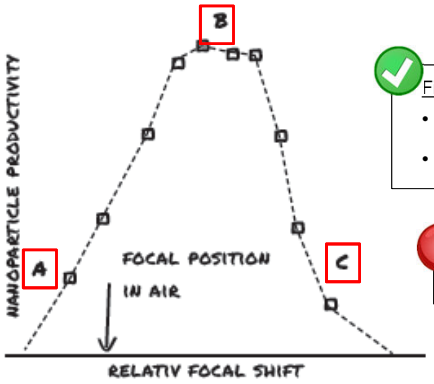
C) If laser is takes renewable energy, it's a fully green tool, with "geen" photons that create matter

D) LAL has unparalleled atom yield of 100%, creating no waste. I call that green chemistry.

E) If the laser operator drives a 3 ton Hummer H2 SUV it will compensate everything

Laser Ablation in Liquid; Working Distance

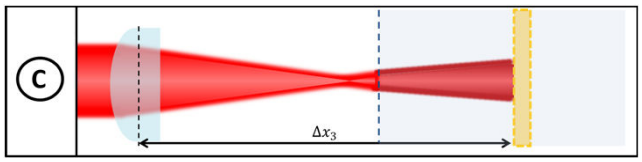
The Working Distance “Hill”



Find the best focal position

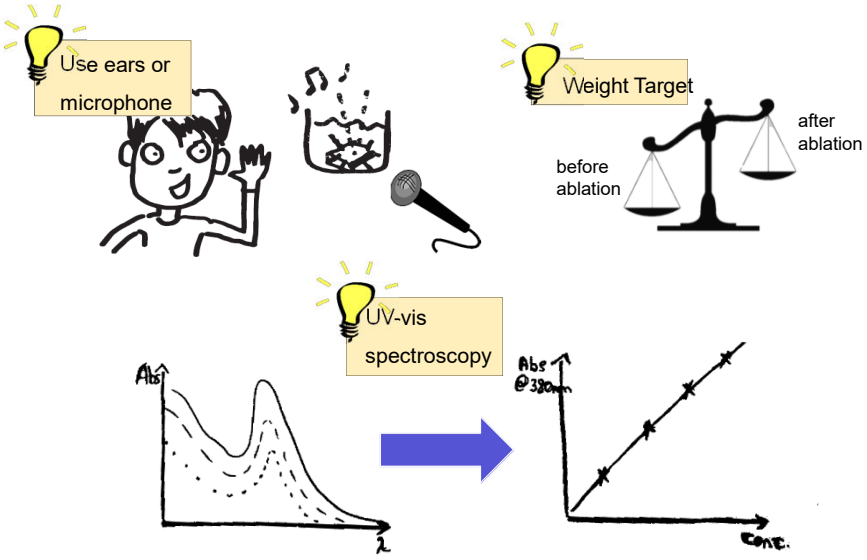
- Start: working distance of focusing lens
- Decrease target-lens-distance

- Don‘t over do! Mind the window!



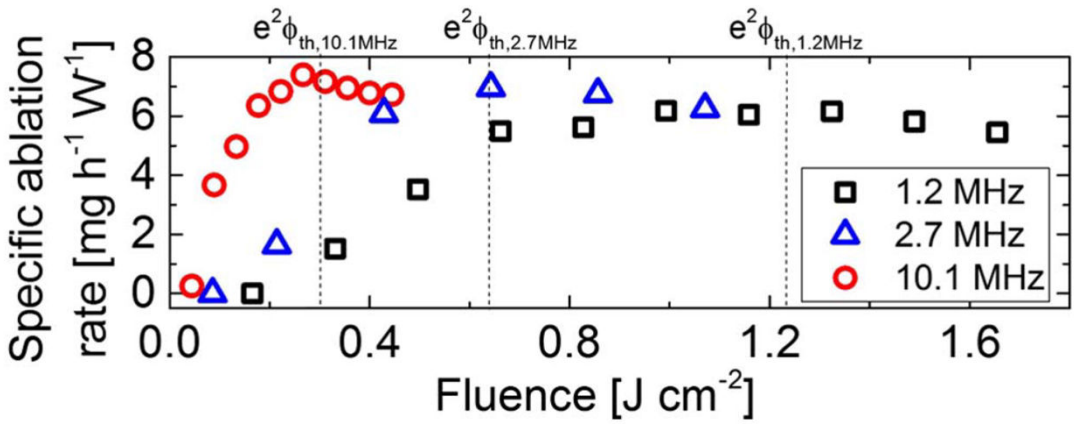
Barcikowski, Amendola, Lau, Marzun, Rehbock, Reichenberger, Zhang, Gökce, Handbook of Laser Synthesis & Processing of Colloids, (2019)

Practical approaches to find the optimal working distance



Barcikowski, Amendola, Lau, Marzun, Rehbock, Reichenberger, Zhang, Gökce, Handbook of Laser Synthesis & Processing of Colloids, (2019)

Fluence Optimum: 7 x Theshold Fluence



R. Streubel, S. Barcikowski, B. Gökce, Optics Letters 41 (2016), 1486

Upscaling Laser Ablation in Liquid
- Drain off the Scatteres -

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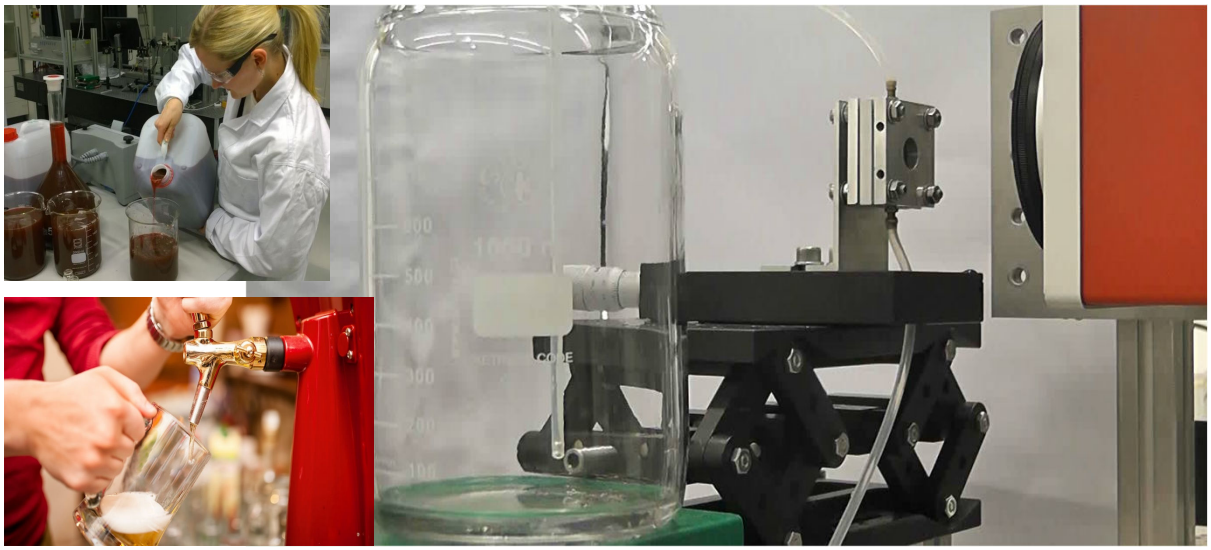
Batch versus Liquid Flow Chamber

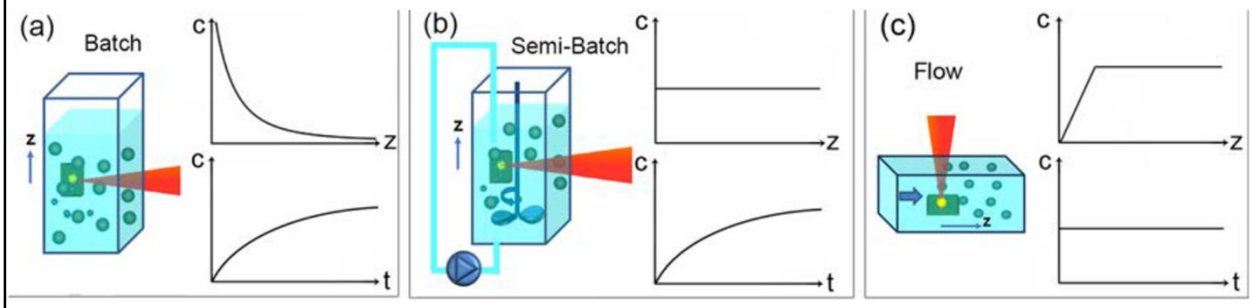
D. Zhang, B. Gökce, S. Barcikowski. Chem Rev. (2017)

Continuous laser synthesis of nanoparticles: „tapping gold“



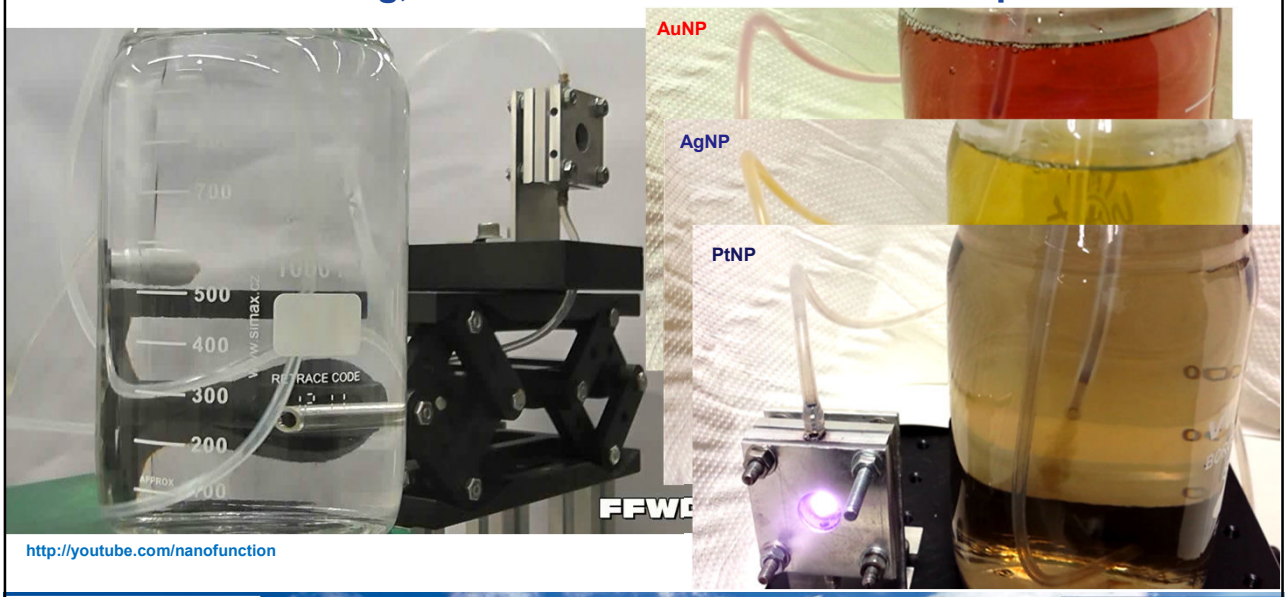
http://youtube.com/nanofunction

Batch versus Liquid Flow Chamber



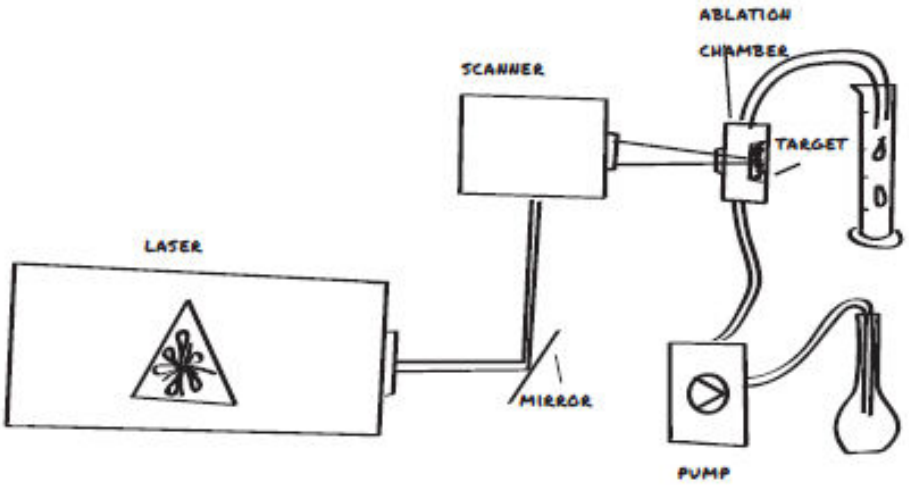
D. Zhang, B. Gökce, S. Barcikowski. Chem Rev. (2017)

Circulating, Continuous Laser Ablation in Liquid



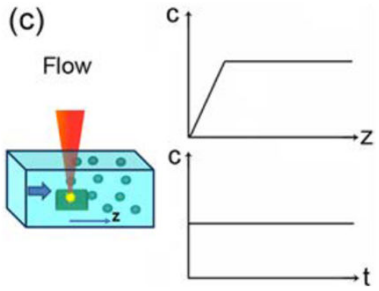
http://youtube.com/nanofunction

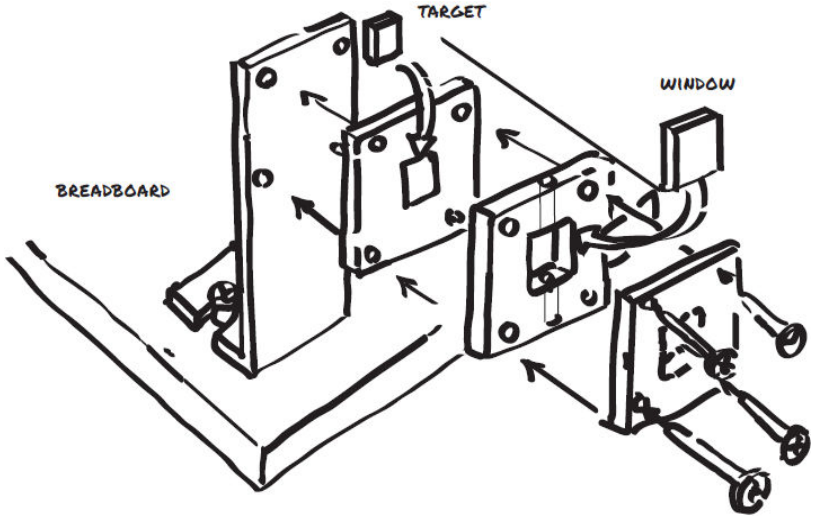
Setup components for decent throughput.



Barcikowski, Amendola, Lau, Marzun, Rehbock, Reichenberger, Zhang, Gökce, Handbook of Laser Synthesis & Processing of Colloids (2019)

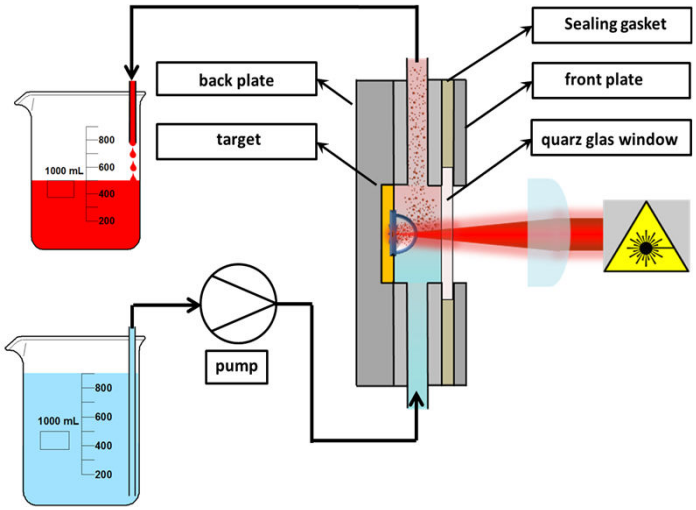
Easy to Make. Choose for > 100 ml Scale





Barcikowski, Amendola, Lau, Marzun, Rehbock, Reichenberger, Zhang, Gökce, Handbook of Laser Synthesis & Processing of Colloids, (2019)

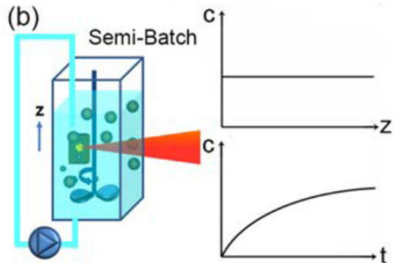
Easy to Make. Choose for > 100 ml Scale

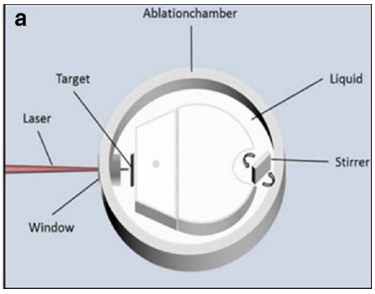


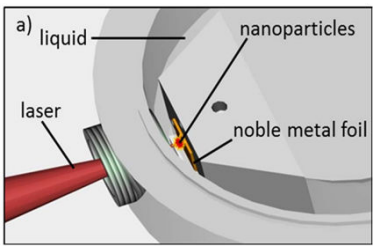
Advantages of contineous flow:

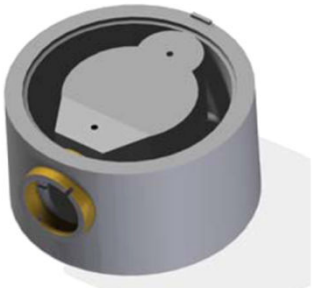
- Stationary conditions
- Controllable NP reirradiation
- Less time consuming assembly
- better scaleability using common dimensionless numbers

For Toolshop Easy to Make. Choose for 30 to 100 ml Scale









P. Nachev, D. D. van't Zand, V. Coger, P. Wagener, K. Reimers, P. M. Vogt, S. Barcikowski, and A. Pich, *J. Laser Appl.*, (2012).

Koenen, S.; Streubel, R.; Jakobi, J.; Schwabe, K.; Krauss, J. K. & Barcikowski, S.. J. Electrochem. Soc., 2015,

Upscaling Laser Ablation in Liquid
- Bypassing the Fruit Bell -

The Fruit Bell

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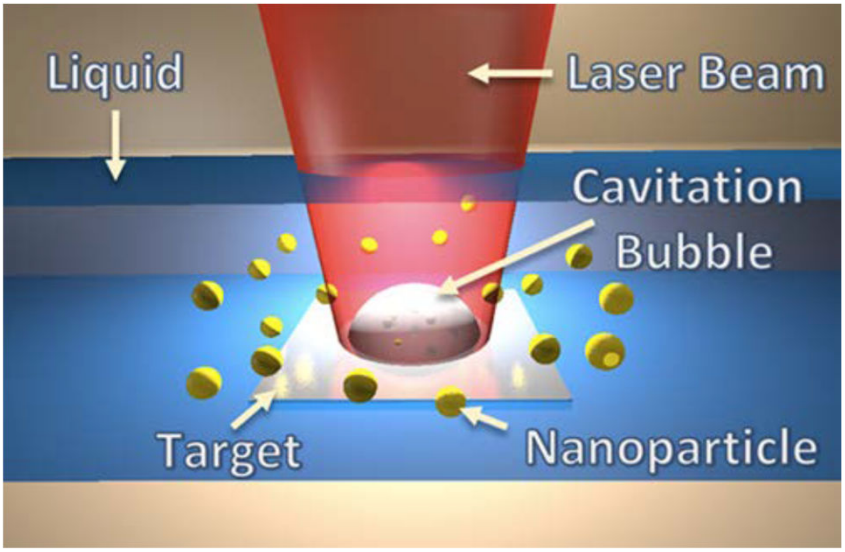
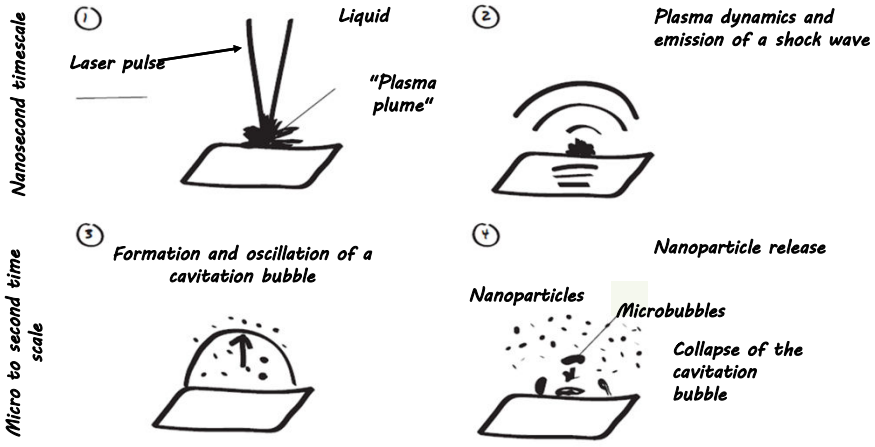
Pulsed Laser Ablation in Liquid (LAL)



D. Zhang, B. Gökce, S. Barcikowski. Chem Rev. (2017)

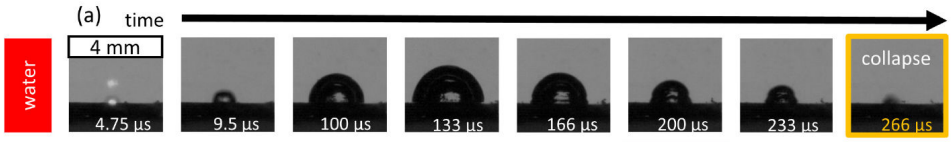
Laser-induced formation of nanoparticles



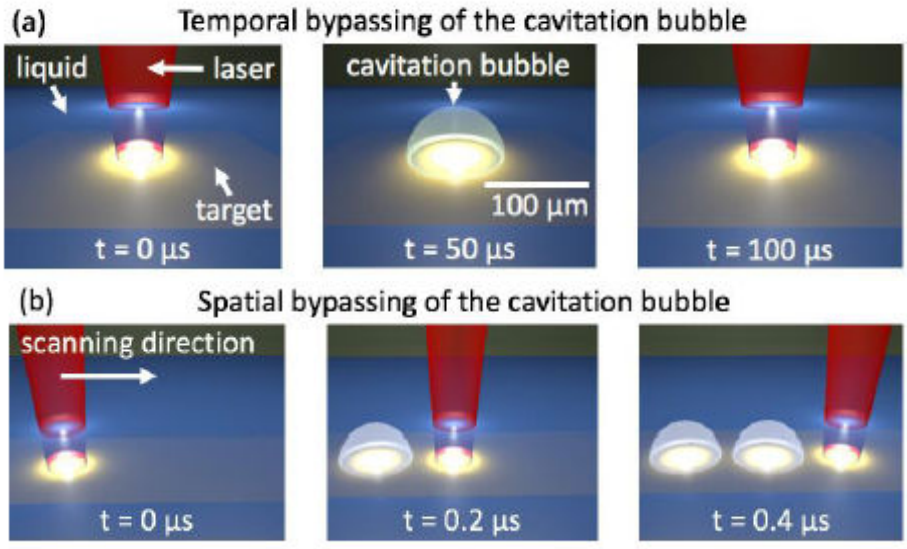
Barcikowski, Amendola, Lau, Marzun, Rehbock, Reichenberger, Zhang, Gökce, Handbook of Laser Synthesis & Processing of Colloids, (2019)

Cavitation Bubble Dynamics

Hupfeld, Laurens, Merabia, Barcikowski, Gökce and Amans, D. *Journal of Applied Physics (2020)*

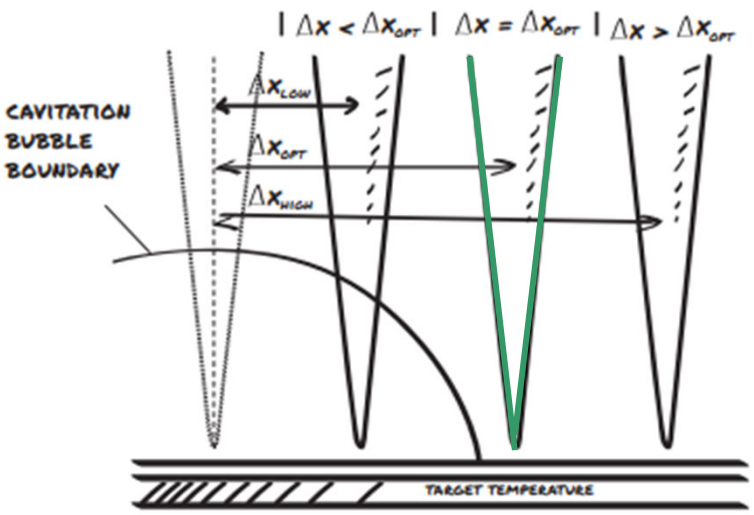


Strategies of Bypassing the Scattering Cavitation Bubble



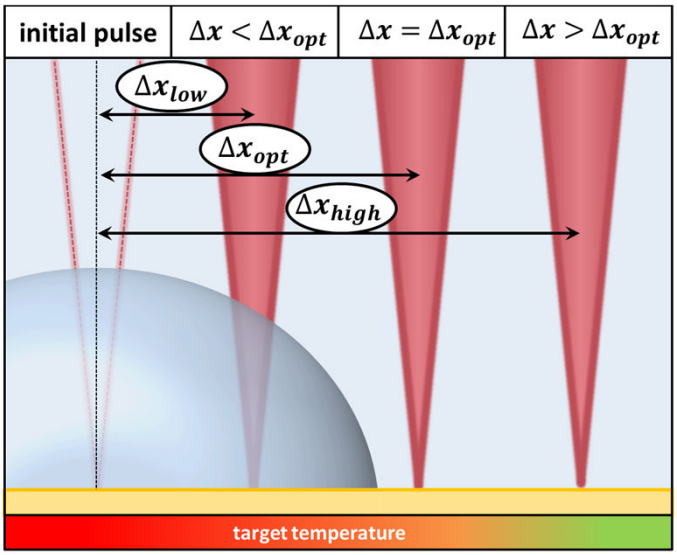
R. Streubel, G. Bendt, B. Gökce. Nanotechnology 27, 205602 (2016)
R. Streubel, S. Barcikowski, B. Gökce, Optics Letters 41 (2016), 1486

Spatial Bypassing Concept



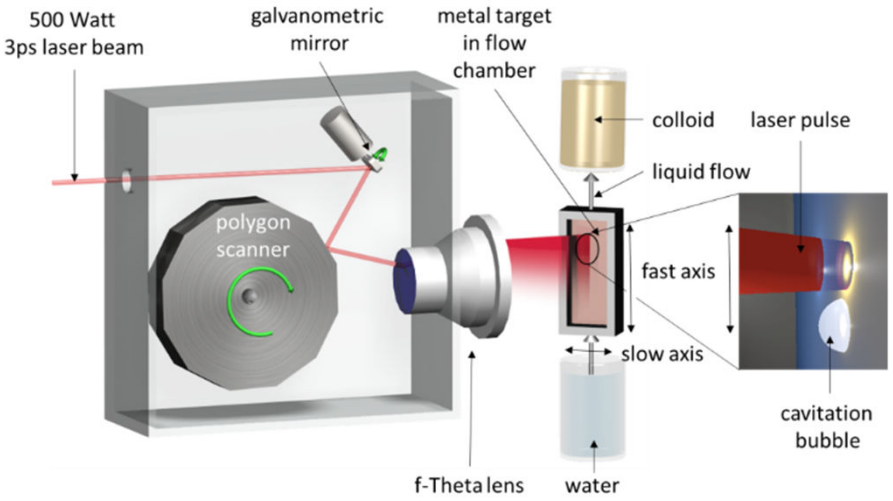
Barcikowski, Amendola, Lau, Marzun, Rehbock, Reichenberger, Zhang, Gökce, Handbook of Laser Synthesis & Processing of Colloids (2019)

Spatial Bypassing Concept



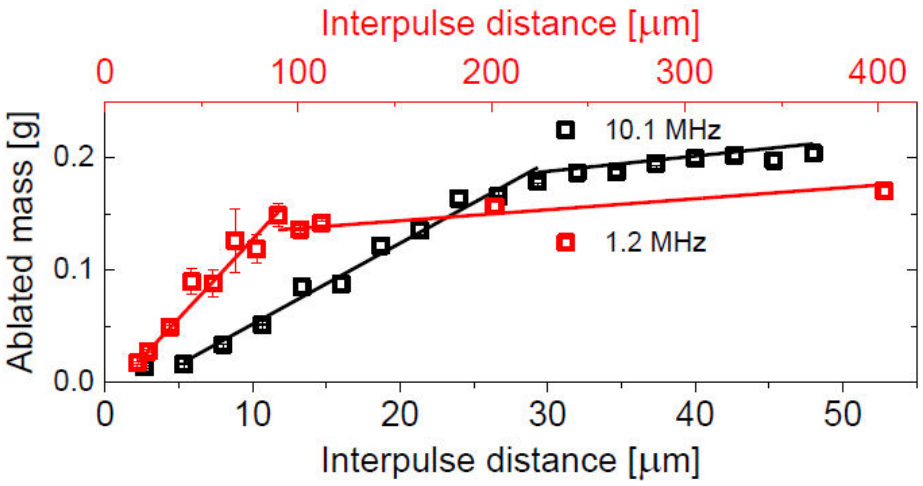
Barcikowski, Amendola, Lau, Marzun, Rehbock, Reichenberger, Zhang, Gökce, Handbook of Laser Synthesis & Processing of Colloids (2019)

500 W, MHz, ps Laser Ablation at High-Speed (500 m/s)



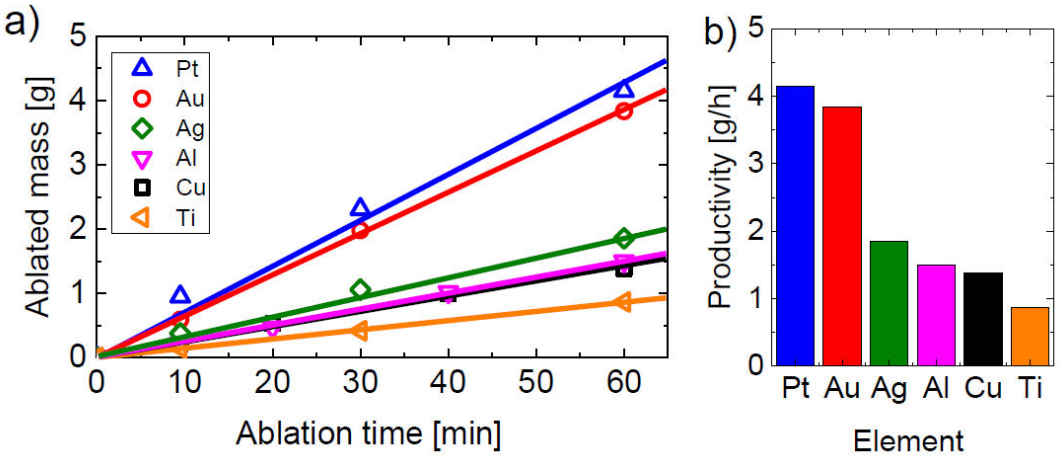
R. Streubel, G. Bendt, B. Gökce. Nanotechnology (2016)
R. Streubel, S. Barcikowski, B. Gökce, Optics Letters (2016)

500 W, MHz, ps Laser Ablation at High-Speed (500 m/s)



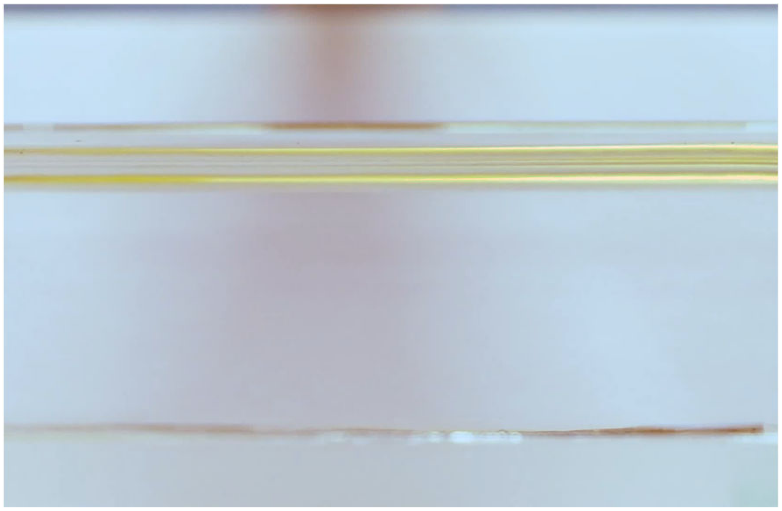
R. Streubel, G. Bendt, B. Gökce. Nanotechnology (2016)
R. Streubel, S. Barcikowski, B. Gökce, Optics Letters (2016)

Linearity of the Process



R. Streubel, G. Bendt, B. Gökce. Nanotechnology 27, 205602 (2016)
R. Streubel, S. Barcikowski, B. Gökce, Optics Letters 41 (2016), 1486

Supersonically-fast, pure, waste-free, cool!



Video Channel: http://youtube.com/nanofunction

Waag, Streubel, Gökce, Barcikowski. Appl. Nanoscience, 2021

Quickie

Which strategies are important to yield more product during LAL?

A) Maximal Laser Power

B) Maximal Laser Fluence

C) Maximal Repetition Rate

D) Hill-Top of Distance between Lens and Target

E) Maximal Lateral Scan Speed

F) Apply Liquid Flow

G) Passion

Upscaling Laser Ablation in Liquid
- The Viscosity Problem -

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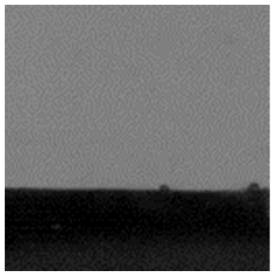
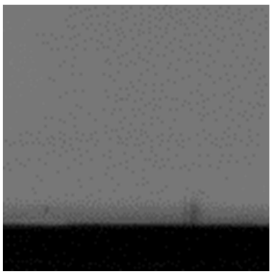
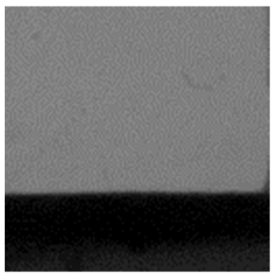
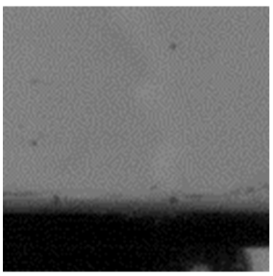
Viscosity Effects


Gold in Water

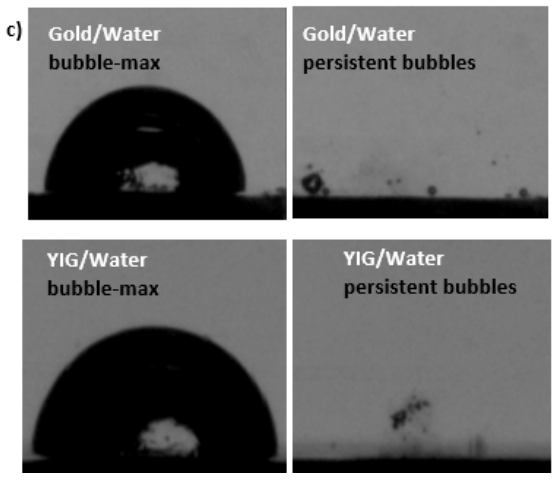

Oxide in Water

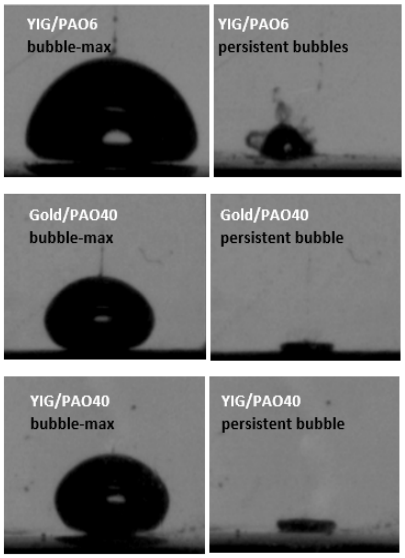

Gold in Oil


Oxide in Oil

Hupfeld, T.; Laurens, G.; Merabia, S.; Barcikowski, S.; Gökce, B. & Amans, D. Journal of Applied Physics, 2020

Viscosity Effects

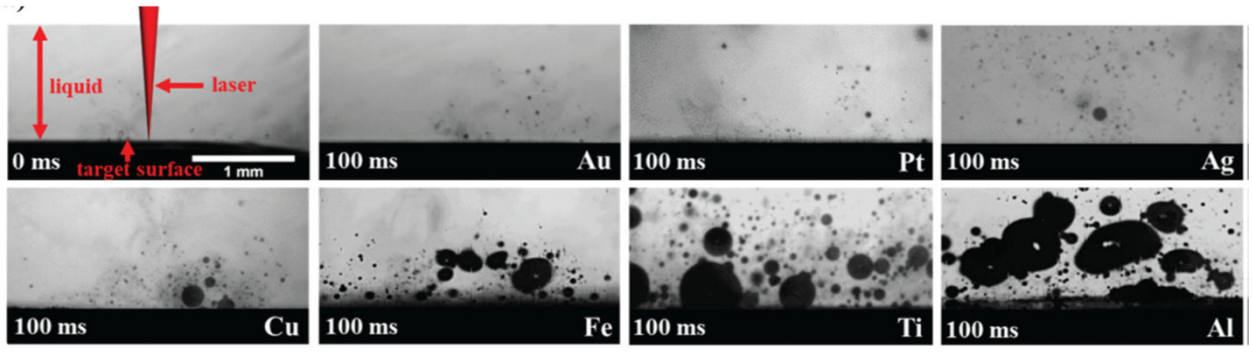




Hupfeld, T.; Laurens, G.; Merabia, S.; Barcikowski, S.; Gökce, B. & Amans, D. Journal of Applied Physics, 2020

Upscaling Laser Ablation in Liquid
- The Sticky Surface Problem -

Material effects on Persistent Gas Bubbles (Images after 100 ms)



Kalus, M.-R.; Lanyumba, R.; Lorenzo-Parodi, N.; Jochmann, M. A.; Kerpen, K.; Hagemann, U.; Schmidt, T. C.; Barcikowski, S. & Gökce, B. *Phys. Chem. Chem. Phys., 2019*

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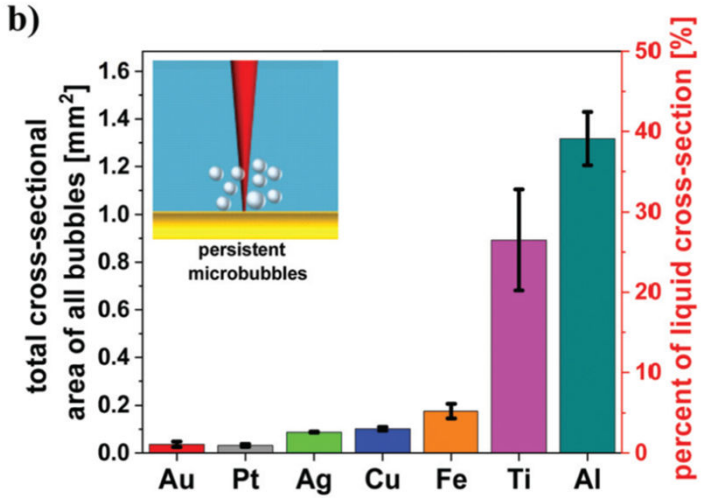
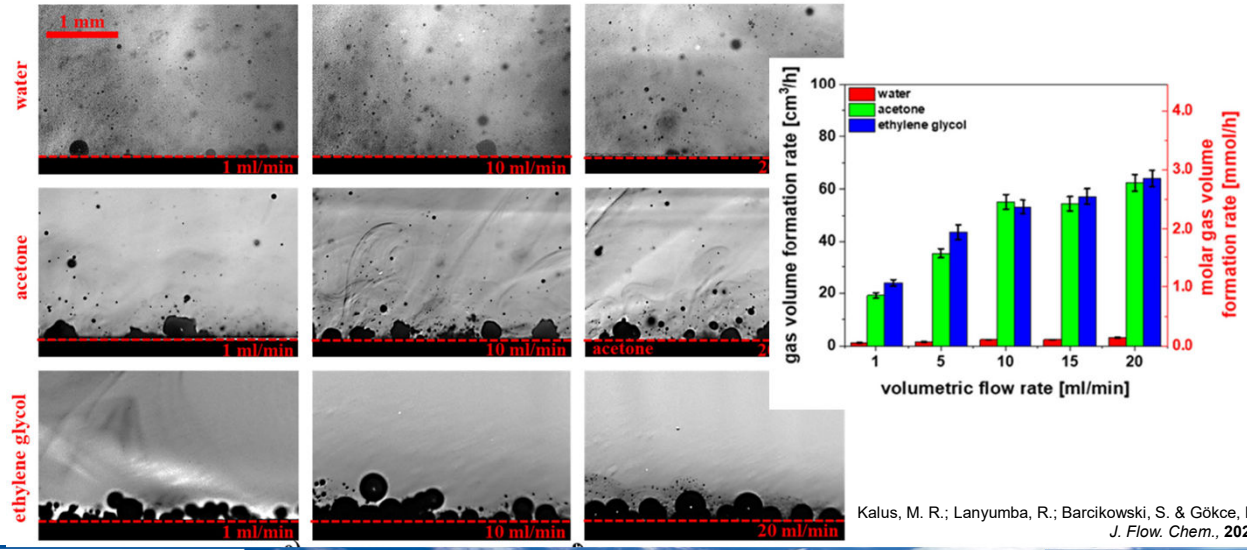
Less noble, more Gas is Formed



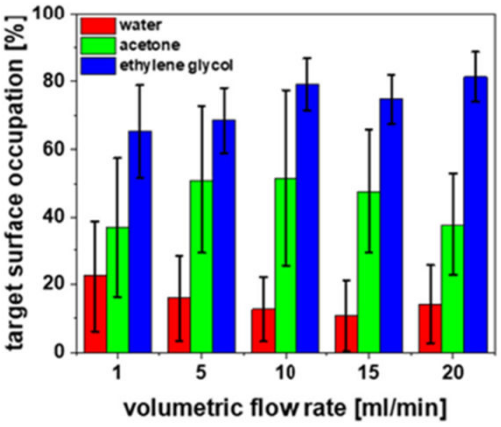
Kalus, M.-R.; Lanyumba, R.; Lorenzo-Parodi, N.; Jochmann, M. A.; Kerpen, K.; Hagemann, U.; Schmidt, T. C.; Barcikowski, S. & Gökce, B. *Phys. Chem. Chem. Phys., 2019*

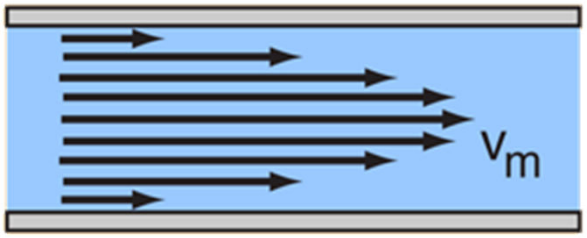
Organic Liquids Create more Gas Bubbles (Images after 10 second)



Kalus, M. R.; Lanyumba, R.; Barcikowski, S. & Gökce, B. *J. Flow. Chem.*, **2021**

The Stickyness Problem





Kalus, M. R.; Lanyumba, R.; Barcikowski, S. & Gökce, B. *J. Flow. Chem.*, **2021**

Upscaling Laser Ablation in Liquid
- The "Buy 1 get 4" Problem -

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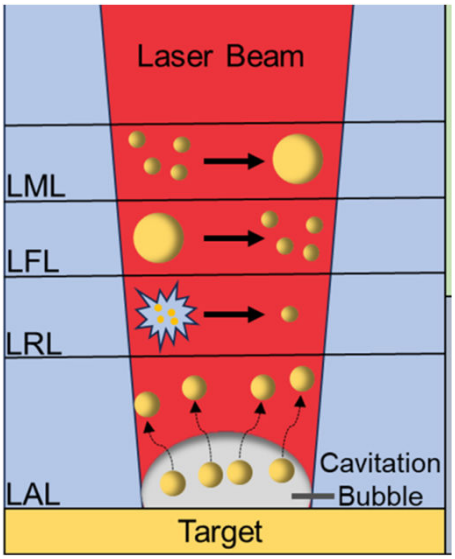
Buy 1 get 4



T. Fromme, S. Reichenberger, K. M. Tibbetts,, S. Barcikwoski. Beilstein J. Nanotechnol. 2024

Laser Processing of Colloids

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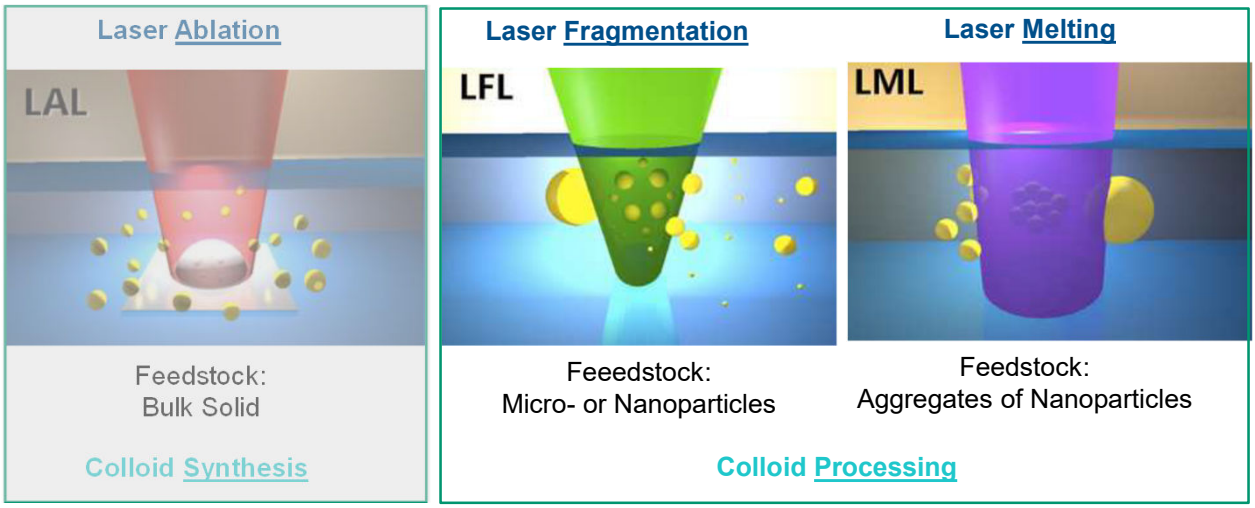
Classification of Laser Synthesis and Processing of Colloids



D. Zhang, B. Gökce, S. Barcikowski. Chem Rev. (2017)

Laser Fragmentation in Liquid (LFL)

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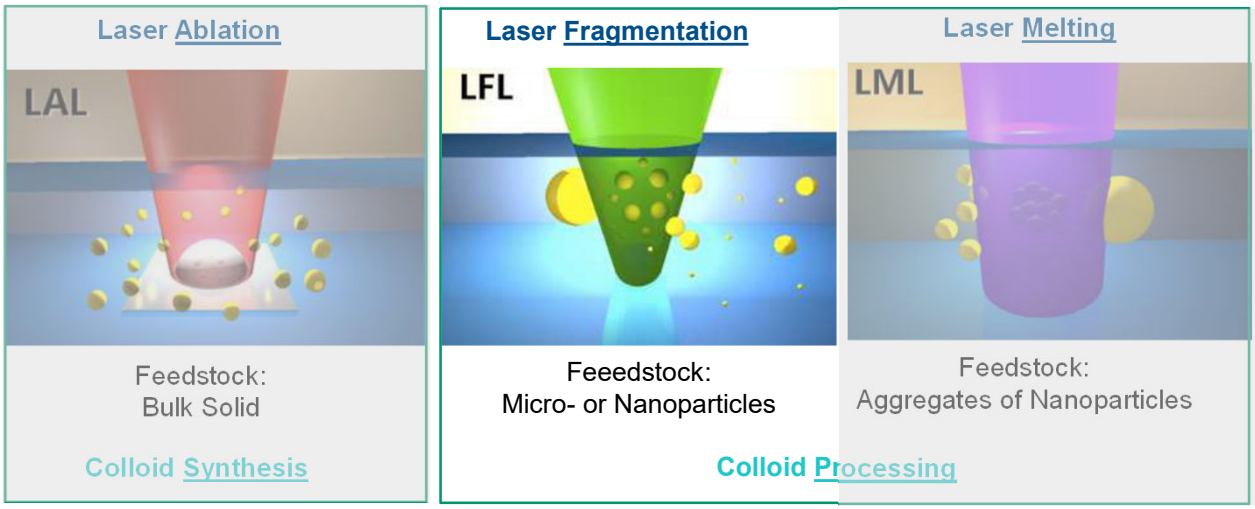
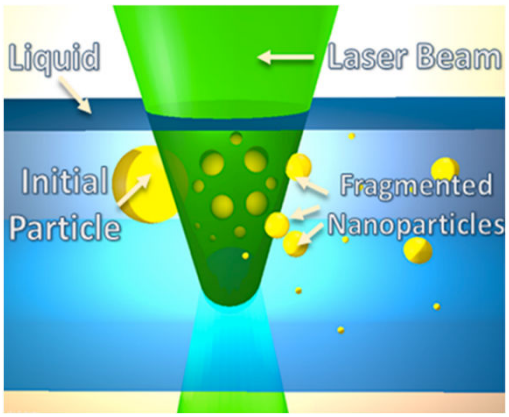
Classification of Laser Synthesis and Processing of Colloids



D. Zhang, B. Gökce, S. Barcikowski. Chem Rev. (2017)

Particle Processing: Laser Fragmentation in Liquid

Laser fragmentation in liquids (LFL)

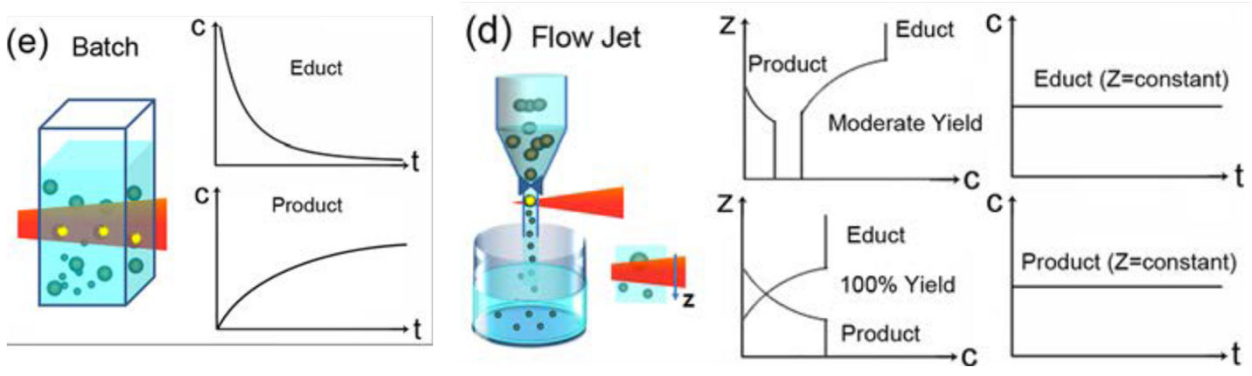


http://youtube.com/nanofunction

D. Zhang, B. Gökce, S. Barcikowski, *Chem. Rev.* 2017.

The Liquid Jet Concept

Fluidführung beim LFL



D. Zhang, B. Gökce, S. Barcikowski. Chem Rev. (2017)

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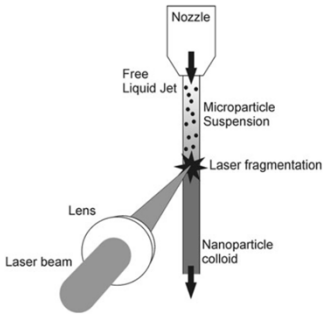
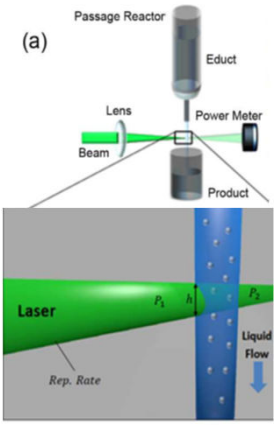
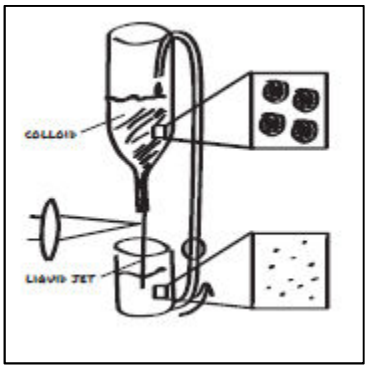
Matching Fluid Flow Speed with Laser Repetition Rate



P. Wagener, S. Barcikowski.
Appl. Phys A (2010)



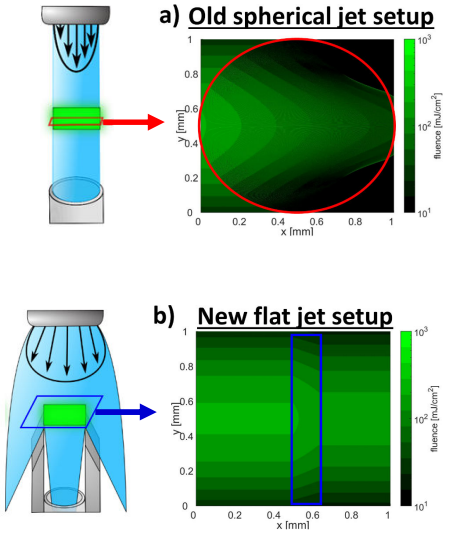
M. Lau, S. Barcikowski.
Appl. Surf. Science (2015)

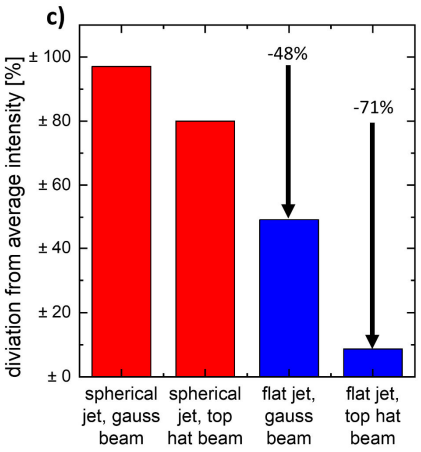


Barcikowski, Amendola, Lau, Marzun, Rehbock, Reichenberger, Zhang, Gökce, Handbook of Laser Synthesis & Processing of Colloids, (2019)

Flat Jet

The Flat Jet Concept: Fluence-sharpened Laser Fragmentation

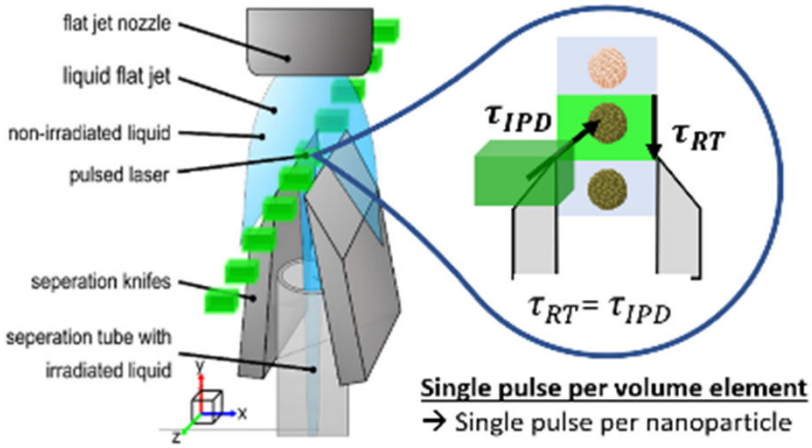




S. Zerebecki, **S. Reichenberger**, S. Barcikowski, J. Phys. Chem. A 2020, 124, 52, 11125–11132

The Pulses-per-Volume (PPV) Element Concept

Matching Repetition Rate with Flow Speed
(in similar: Interpulse Interval with Residence Time)

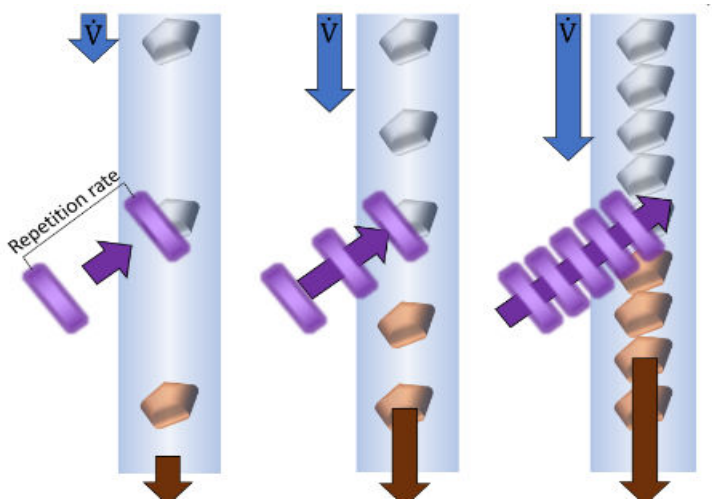


Single pulse per volume element
→ Single pulse per nanoparticle

S. Zerebecki, S. **Reichenberger**, S. Barcikowski, J. Phys. Chem. A (2020)

Budiyanto, Zerebecki, Weidenthaler, DeBeer, Rüdiger, **Reichenberger**, Barcikowski, Tüysüz. ACS Appl. Mater. Interf., (2021)

Throughput Increase at 1 Pulse Per Volume Element (1 PPV) via Rep Rate



Size Control

Quickie

What size are often hunted for?

A) The smallest, at least for catalysis

B) The narrowest

C) Catalysis: ca. 5 nm, Bio: ca. 10 nm, Plasmonics ca. 50 nm.

D) In application: Where effort and functionality is balanced.

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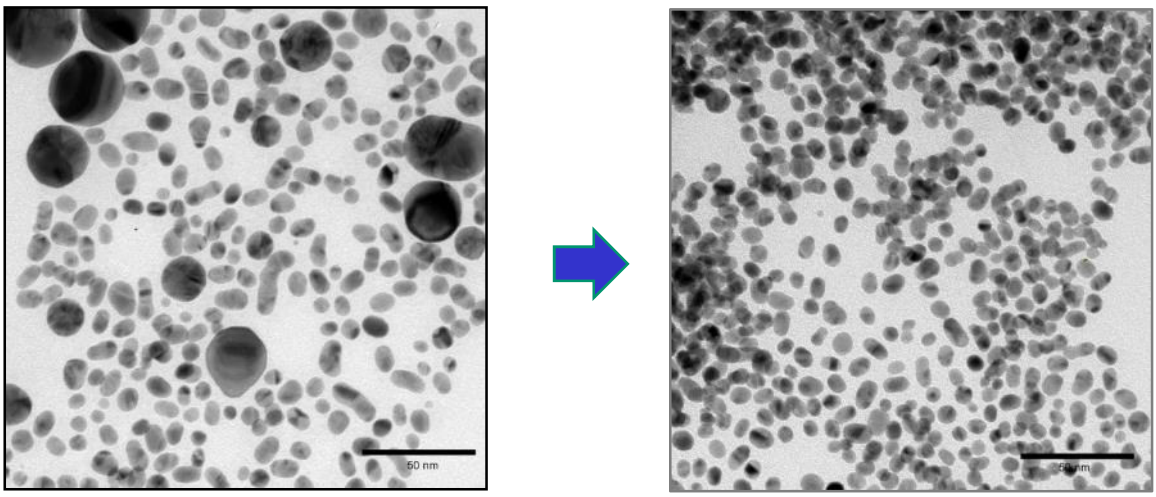
Size Control
by Surface Charge Delivery

In Situ Size Quenching by Anions during Laser Ablation



Rehbock, C.; Merk, V.; Gamrad, L.; Streubel, R. & Barcikowski, S. Physical Chemistry Chemical Physics, 2013

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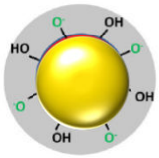
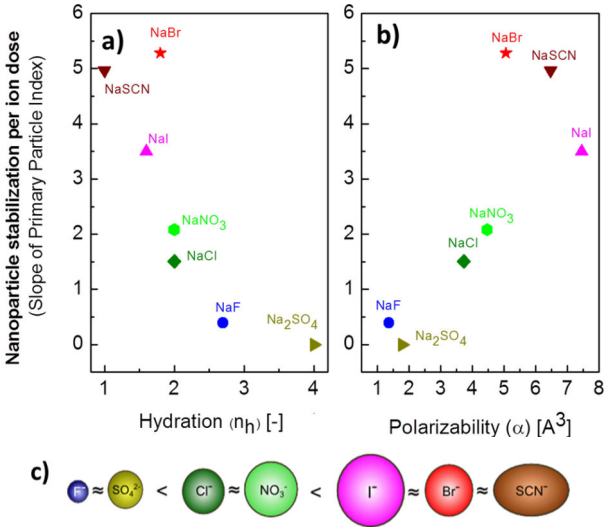
Surface Charge of laser-generated nanoparticles



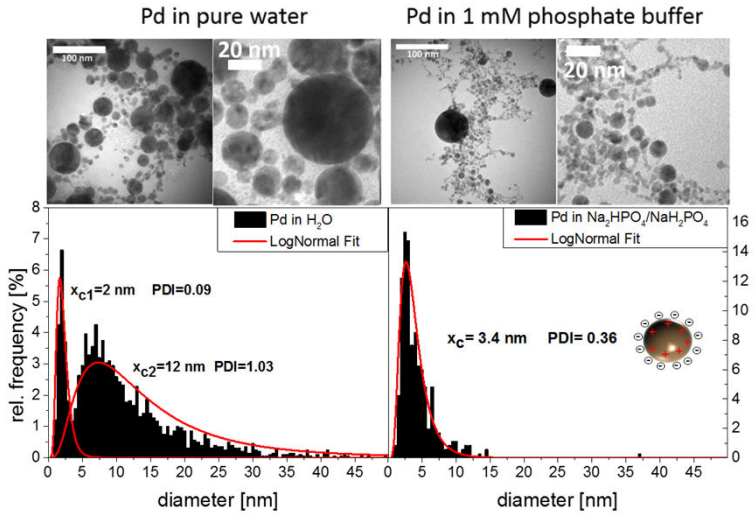
Rehbock; Barcikowski et al.; *PCCP 2013*
Pfeiffer, Barcikowski, Parak et al.,, *J. R. Soc. Interface 2014*

Ion Specifity of Charge Transfer



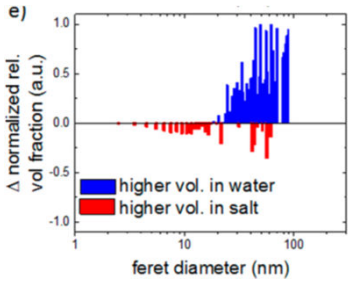
V. Merk, C. Rehbock, F. Becker, U. Hagemann, H. Nienhaus, S. Barcikowski, Langmuir (2014)

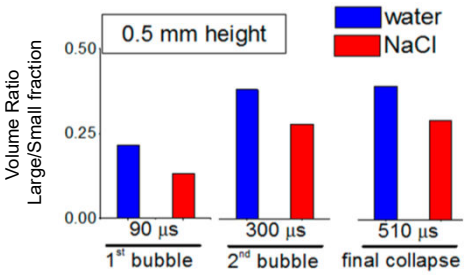
Size quenching and stabilizing effect of salt

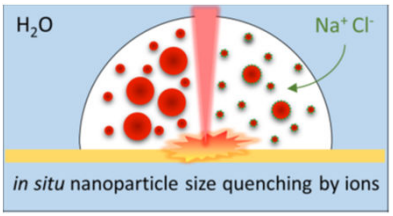


G. Marzun, J. Nakamura, X. Zhang, S. Barcikowski, P. Wagener, *Applied Surface Science* 348 (2015) 75-84

Size Quenching Happens INSIDE of the Cavitation Bubble

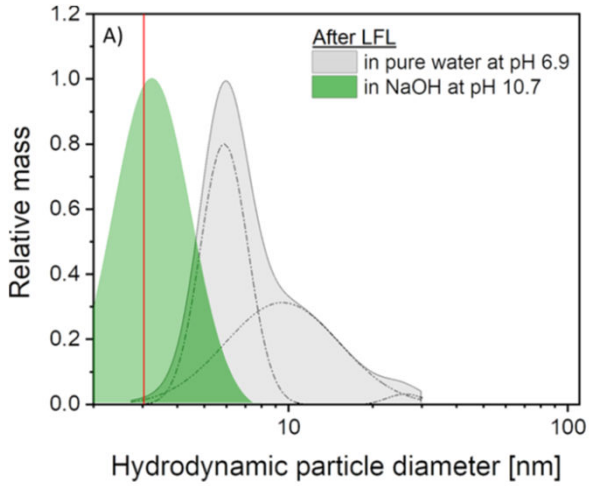


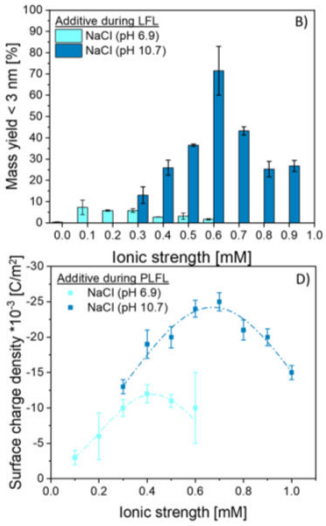




Letzel, A. ; Goekce, B. ; Wagener, P. ; Ibrahimkutty, S. ; Menzel, A. ; Plech, A. ; Barcikowski, S.: JPCC (2017), 1175-1184

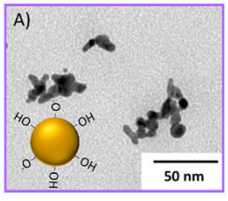
Laser Fragmentation – Anion Effects

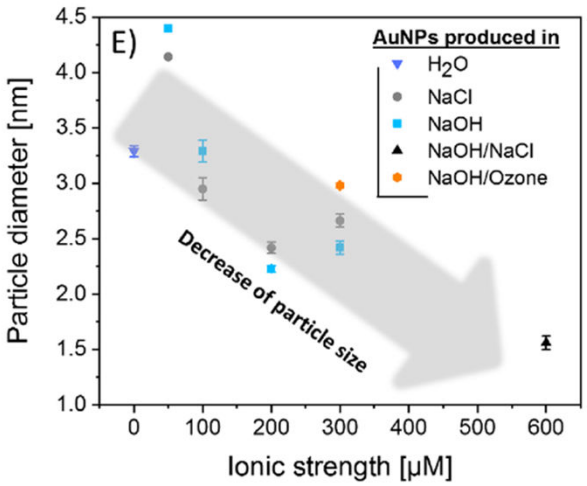


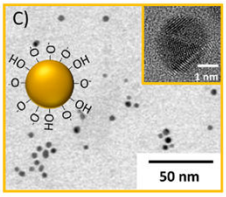


A. Ziefuß, S. Reichenberger, C. Rehbock, I. Chakraborty, M. Gharib,W. J. Parak, S. Barcikowski. J. Phys. Chem. C (2018), 122, 22125−22136

In Situ Size Quenching by Anions during Laser Fragmentation

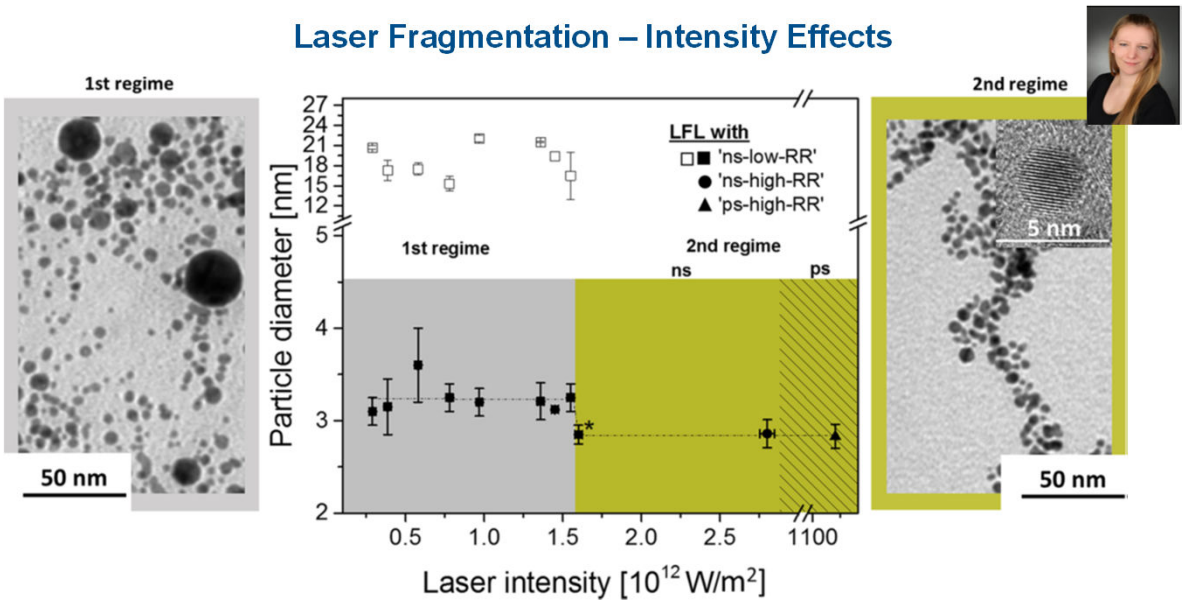






Ziefuss, A. R.; Reichenberger, S.; Rehbock, C.; Chakraborty, I.; Gharib, M.; Parak, W. J. & Barcikowski, S. The Journal of Physical Chemistry C, 2018

Laser Fragmentation – Intensity Effects



A. Ziefuß, S. Reichenberger, C. Rehbock, I. Chakraborty, M. Gharib,W. J. Parak, S. Barcikowski. J. Phys. Chem. C (2018), 122, 22125−22136

Sub-nanometer precision, surface charge control

RESEARCH ARTICLE

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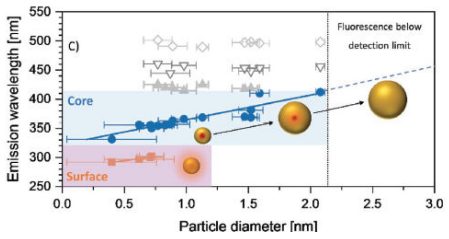
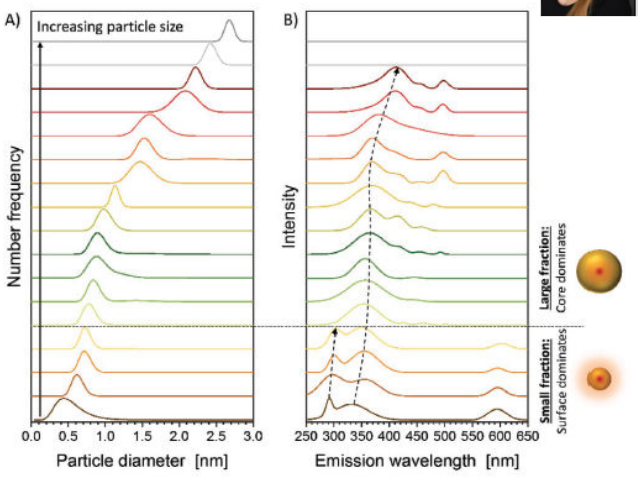
Photoluminescence of Fully Inorganic Colloidal Gold Nanocluster and Their Manipulation Using Surface Charge Effects

*Anna R. Ziefuss, Torben Steenbock, Dominik Benner, Anton Plech, Jörg Göttlicher, Melissa Teubner, Benjamin Grimm-Lebsanft, Christoph Rehbock, Clothilde Comby-Zerbino, Rodolphe Antoine, David Amans, Indranath Chakraborty, Gabriel Bester, Milen Nachev, Bernd Sures, Michael Rübhausen, Wolfgang J. Parak, and Stephan Barcikowski**

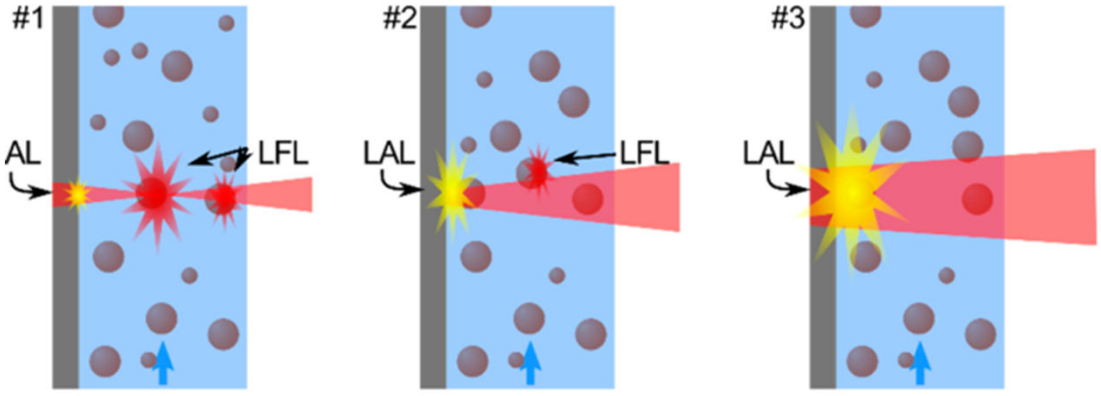




Ziefuss ....., Barcikowski. Adv. Mater. 2021

Size Control by
In-Process Combination of
Ablation and Fragmentation

Balancing LAL and in-process LFL



Dittrich, S.; Kohsakowski, S.; Wittek, B.; Hengst, C.; Gökce, B.; Barcikowski, S. & Reichenberger, S. *Nanomaterials,* **2020**

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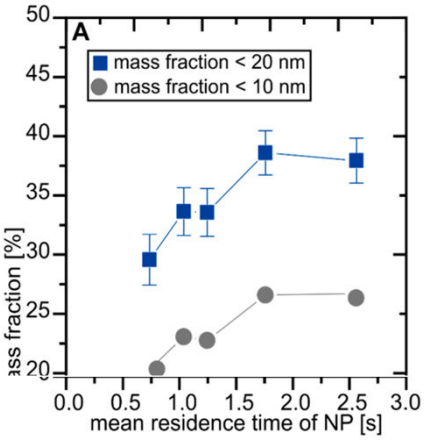
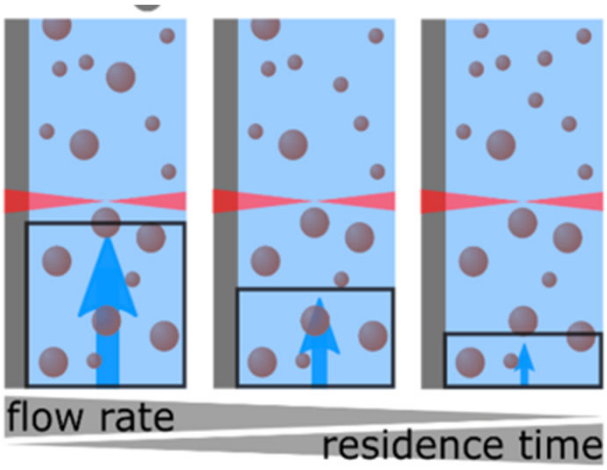
Residence time Efects on Small Fraction Yield during Combined LAL+LFL

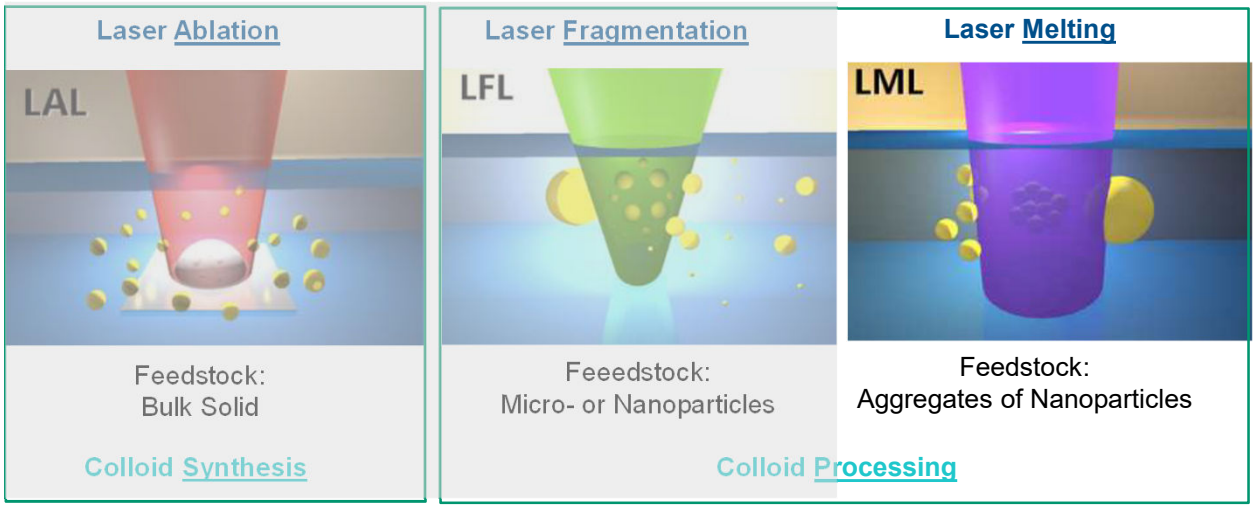




Dittrich, S.; Kohsakowski, S.; Wittek, B.; Hengst, C.; Gökce, B.; Barcikowski, S. & Reichenberger, S. *Nanomaterials,* **2020**

Laser Melting in Liquid (LML)

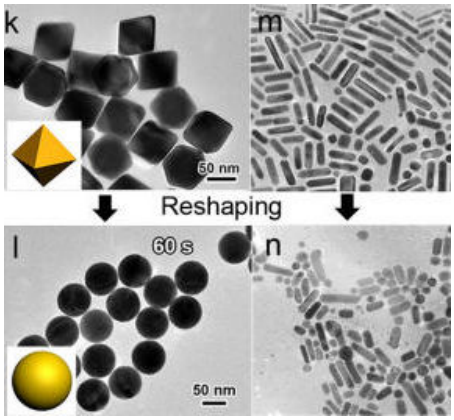
Classification of Laser Synthesis and Processing of Colloids



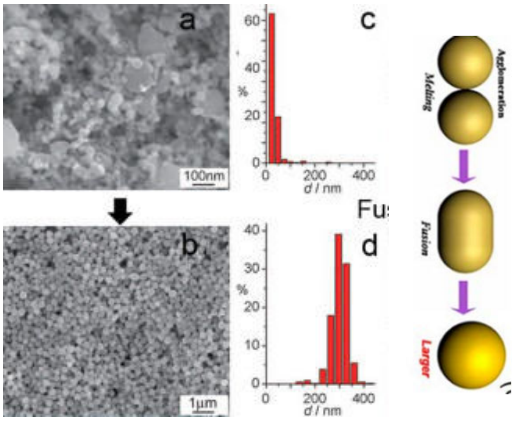
D. Zhang, B. Gökce, S. Barcikowski. Chem Rev. (2017)

2 Variants of Pulsed Laser Melting in Liquids

Reshaping (Isochoric)



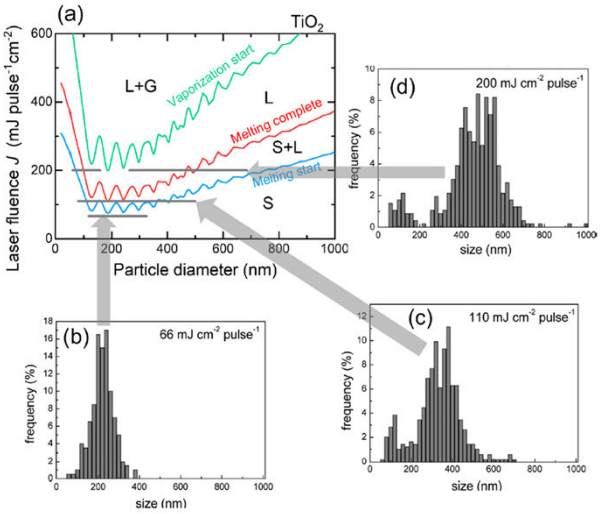
Fusion – Melting (Size increase)



D. Zhang, B. Gökce, S. Barcikowski. Chem Rev. (2017)

Laser Melting in Liquid
- Fluence Effects -

2 Variants of Pulsed Laser Melting in Liquids



Y. Ishikawa, T. Tsuji, S. Sakaki and N. Koshizaki, Progress in Materials Science 2023
Y. Ishikawa, N. Koshizaki, A. Pyatenko, N. Saitoh, N. Yoshizawa and Y. Shimizu, Journal of Physical Chemistry C 2016

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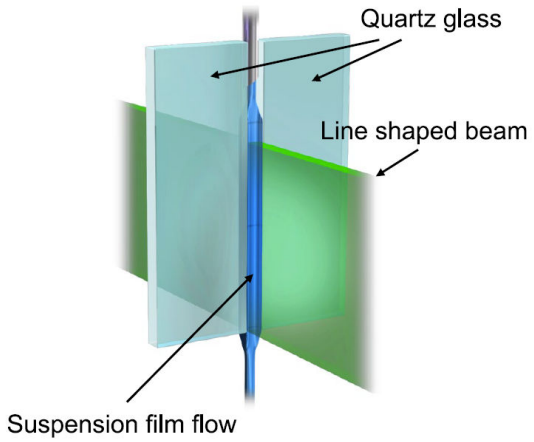
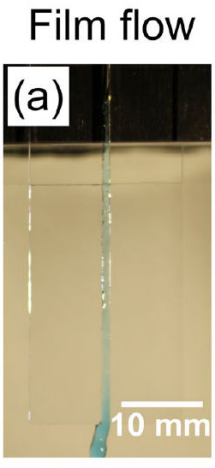
Laser Melting in Liquid
- Pulse Number Effects -

Continuous-Flow Laser Melting in Liquids





Ishikawa, Koshizaki. *Scientific Reports* (2018)

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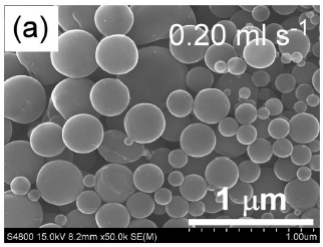
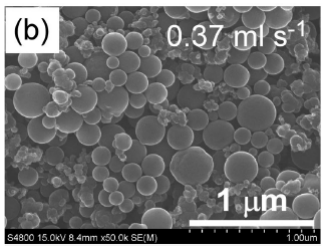
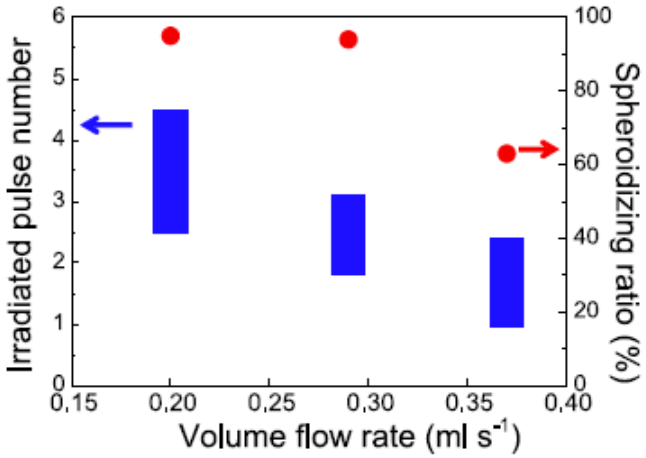
More than one Pulse per Volume Element required



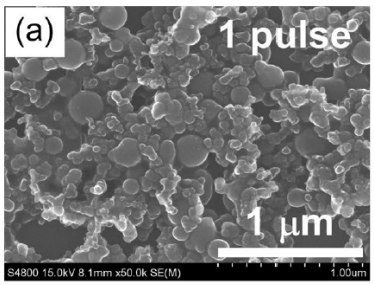


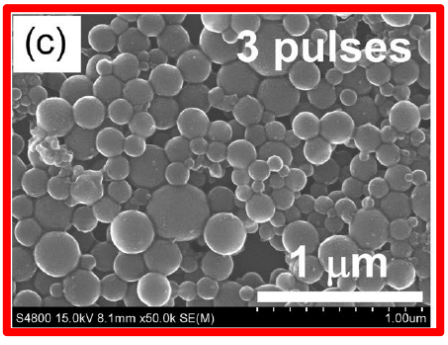


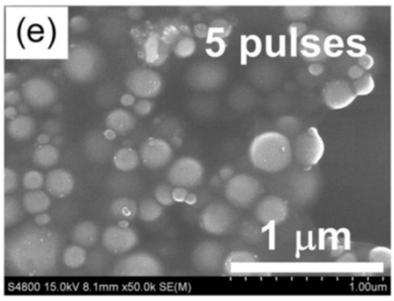
Ishikawa, Koshizaki.*Scientific Reports* (2018)

Optimal Pulses per Volume Element

Optimum



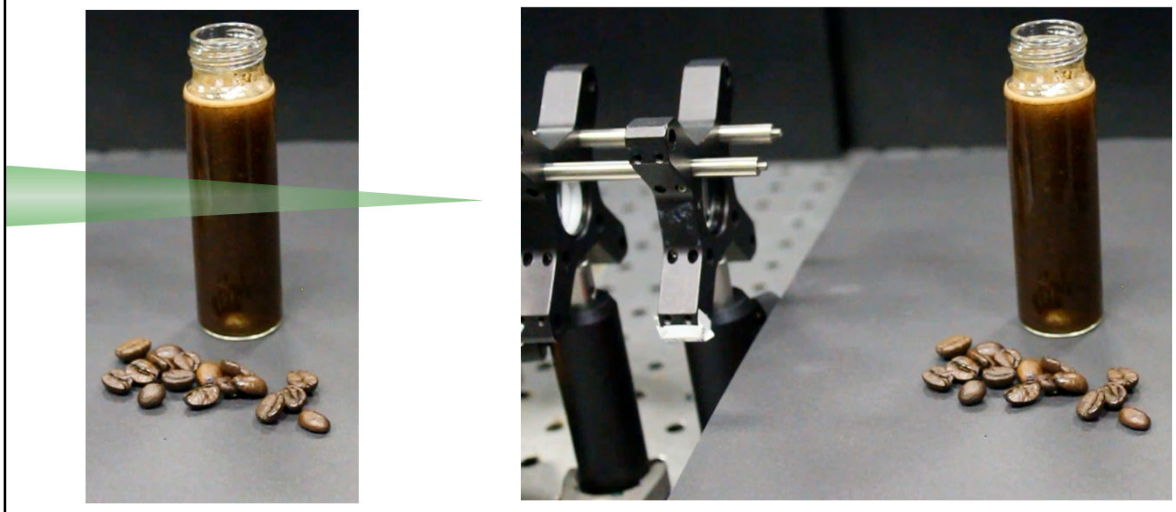




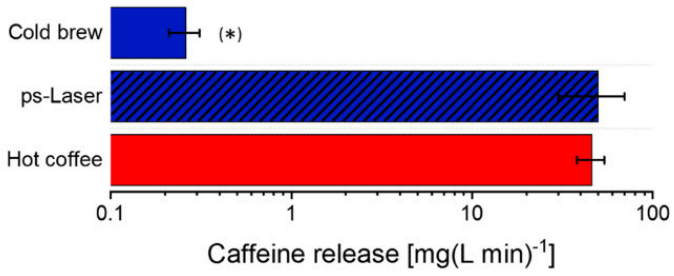
Ishikawa, Koshizaki.*Scientific Reports* (2018)

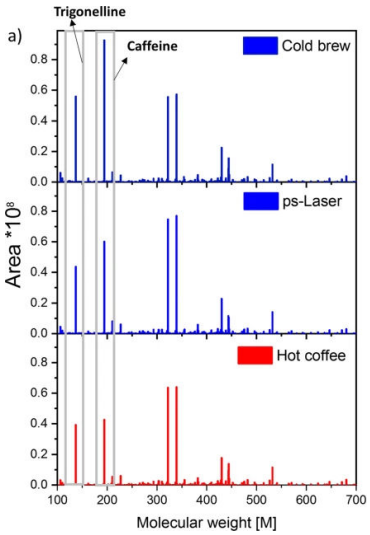
Friday Evening Experiment

Pulsed Laser Coffee Extraxtion



Ultrafast Laser Cold Extraction of Coffee





Anna R. **Ziefuss**, Tim Hupfeld, Sven W. Meckelmann, Martin Meyer, Oliver J. Schmitz, Wiebke Kaziur-Cegla, Lucie K. Tintrop, Torsten C. Schmidt, Bilal Gökce & Stephan Barcikowski. Science of Food (2022)

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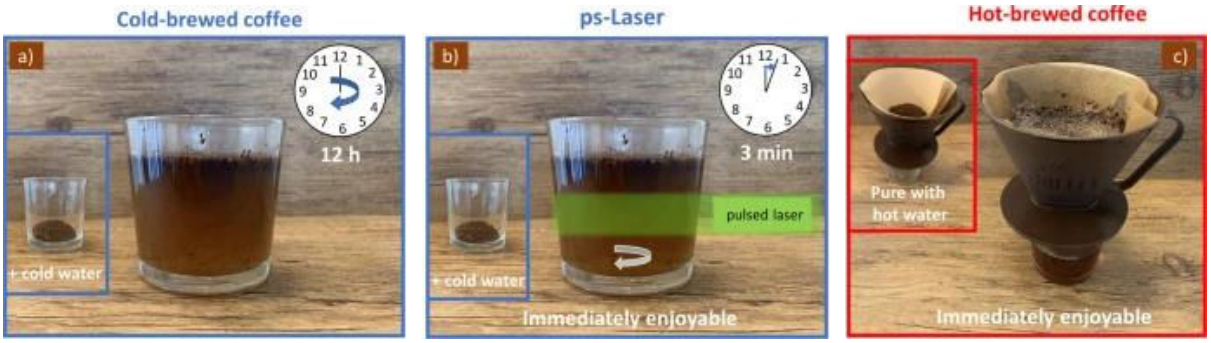

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Online Reception of Laser-Coffee

DAILY COFFEE NEWS
BY roast MAGAZINE

ROASTING RETAIL ORIGIN INDUSTRY ESPAÑOL

Beam Me Cup, Scotty; German Scientists Make Cold Brew With Lasers

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HIGH CULTURE — AUGUST 2, 2022

Scientists make cold brew coffee in 3 minutes using lasers

This is a great improvement over the typical brew time of 12 to 18 hours.

FAST COMPANY

08-17-22

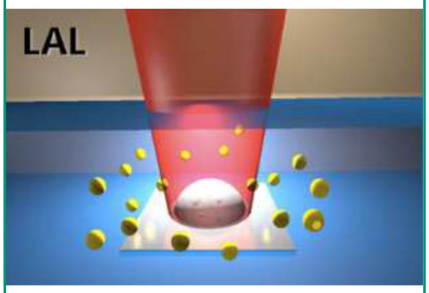
Cold brew coffee—pew, pew, pew—brewed with lasers!

A new laser technology creates cold brew coffee in minutes. Even better: it tastes just as good and may be coming to a coffee shop near you.

Summary

Classification of Laser Synthesis and Processing of Colloids

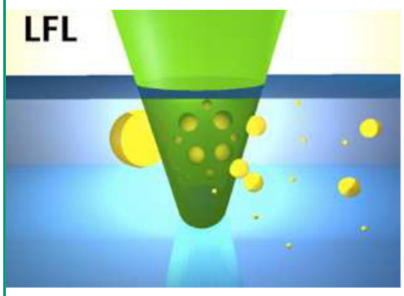
Laser Ablation



Feedstock:
Bulk Solid

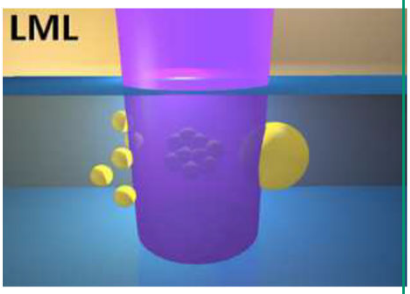
Colloid Synthesis

Laser Fragmentation



Feeedstock:
Micro- or Nanoparticles

Laser Melting



Feedstock:
Aggregates of Nanoparticles

Colloid Processing

D. Zhang, B. Gökce, S. Barcikowski. Chem Rev. (2017)

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Thank You !

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STAR WARS
EPISODE IV
ATTACK OF ANGELA MERKEL
TAKING OVER THE EMPIRE
IN THEATERS SEPTEMBER 2005
MAY THE FORCE
BE WITH US!