TECHNISCHE UNIVERSITÄT DRESDEN

INGEDE International Association of the Deinking Industry

Faculty of Mechanical Engineering. Institute of Wood- and Paper technology. Chair for Papermaking

Ultrasound Deinking

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INGEDE-Project 119 08

Sofia, May 2011

contents

project objectives

On the basis of

- a comprehensive literature survey as well as
- accompanying laboratory work

the project aimed at providing a meaningful evaluation and assessment of the potential ultrasound technology (US) might bear with respect to significantly improve de-inking processes.

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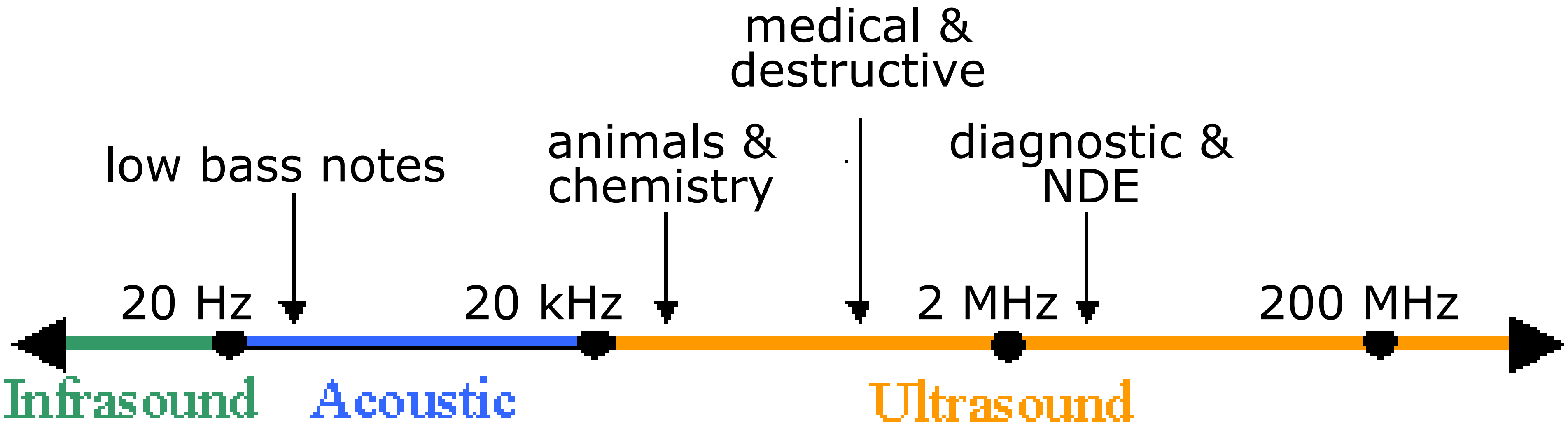
what is ultrasound?



Ultrasound waves are generated through the conversion of energy

- mechanical
- thermal
- electromechanical
- optical

Today US generators based on the converison of electromechanical energy through piezo-electrical effects are by far the most important

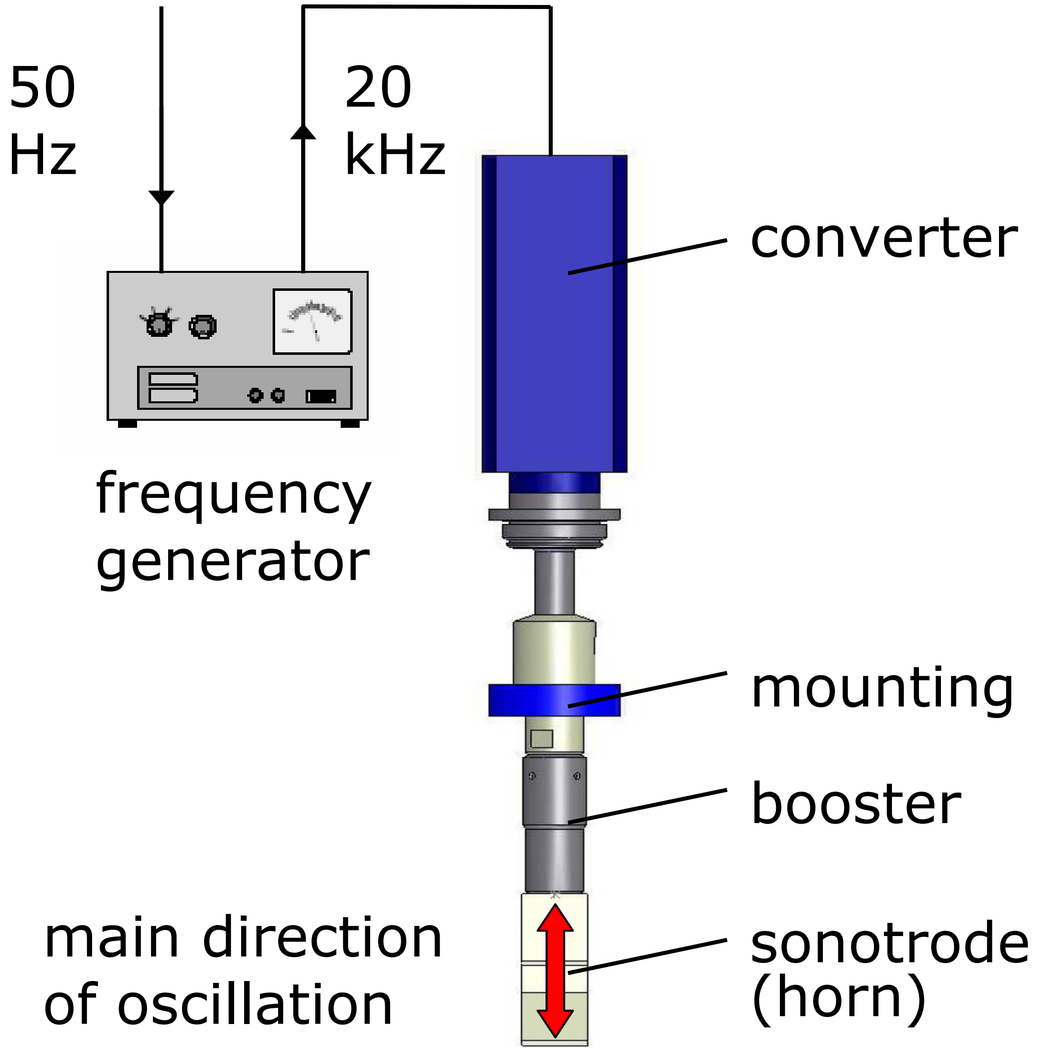
piezoelectric ultrasound system

variables:

- amplitude by frequency generator or voltage of the converter
- amplitude by different boosters
- exposure time
- acoustic intensity [W/cm²] (energy transfer to medium by and geometry of the sonotrode)

fixed parameters:

- ultrasound frequency



ultrasound effects

ultrasound effects can be divided in two main classes

primary effects

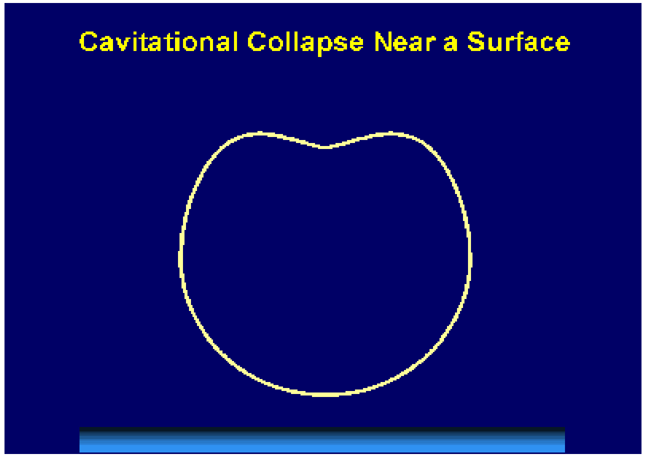
- mechanical effects (i.e. displacement of particles, alternating pressure)

secondary effects

- effects to reach specific process aims in engineering (cavitation, disintegration)

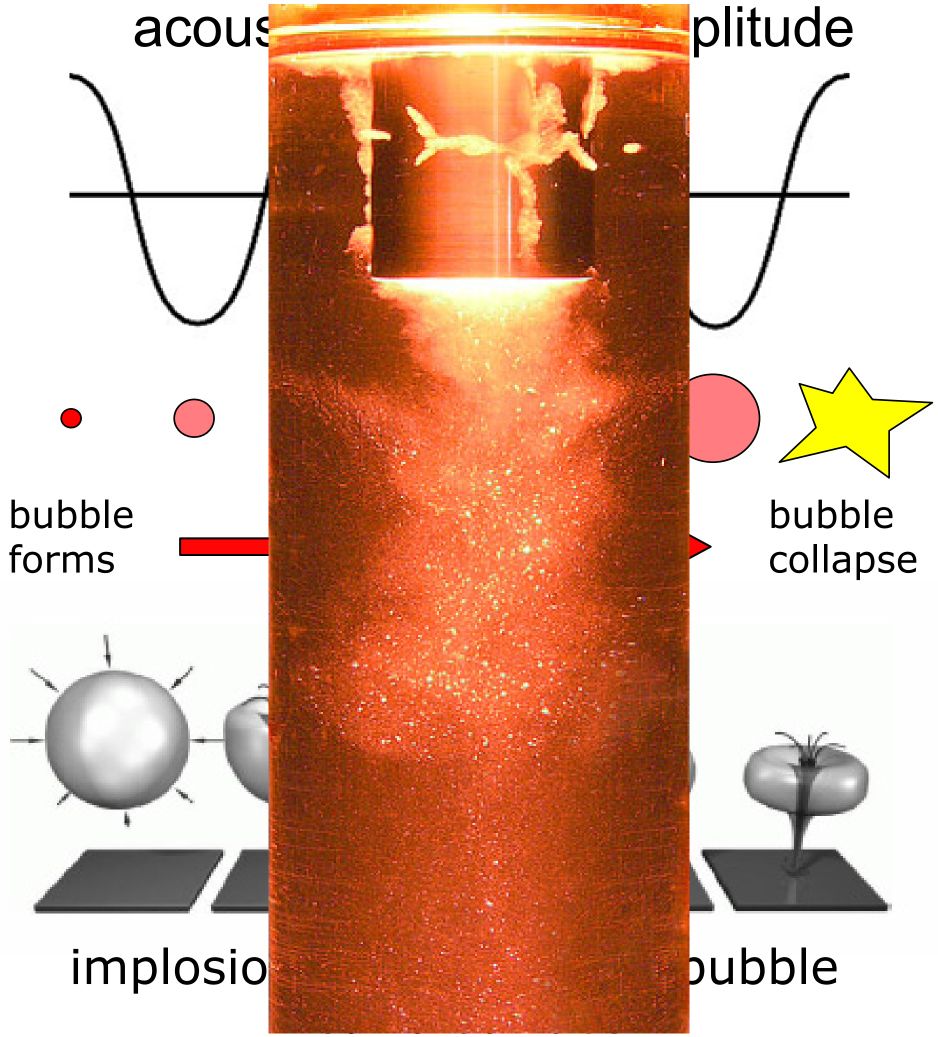
cavitation is considered the main pheno-menon causing most ultrasound effects in or on the treated medium.

Many applications are driven by acoustic cavitation, described briefly as the growth, oscillation and collapse of microbubbles in the medium of interest



ultrasound effect of cavitation

- vapour bubbles form in fluids due to high frequency pressure fluctuations
- bubbles deform in heterogeneous fluids/suspensions because of the imbalance within the pressure field
- eventually, at a certain pressure level, bubbles violently implode
- pressure peaks > 100 MPa occur
- micro jets are generated that impinge on the surface of neighbouring solid matter
- impinging micro jets exert strong mechanical forces on the surfaces hit



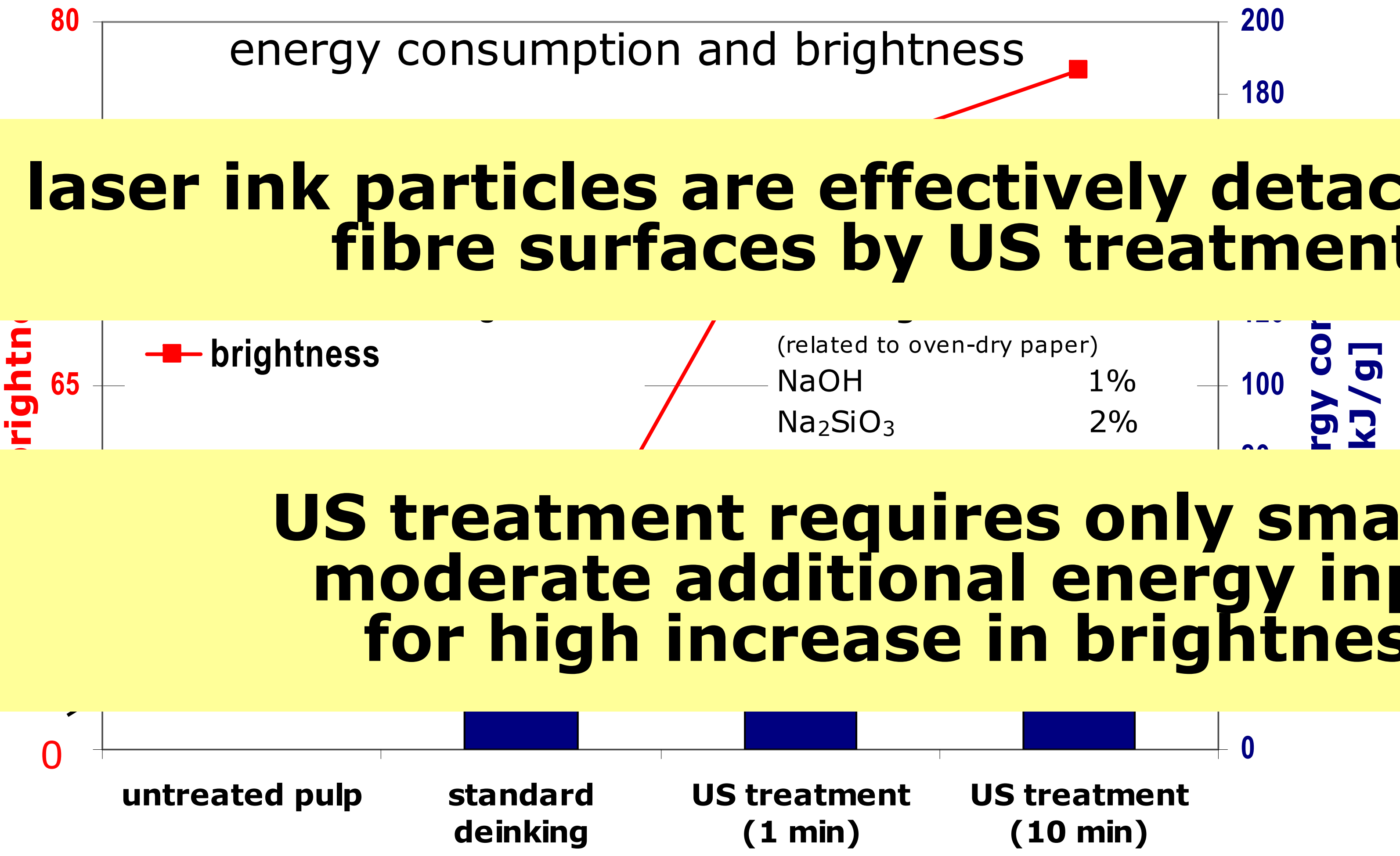
Source: Y. Schneider: Einsatz von Ultraschall zur Modifikation lebensmitteltechnischer Grundoperationen am Beispiel des Schneidens. Dissertation. 2006
T. J. Mason: An Introduction to Sonochemistry. THE SONOCHEMISTRY CENTRE AT COVENTRY UNIVERSITY. http://www.sonochemistry.info. 2007
Hielscher Ultrasonics GmbH. http://www.hielscher.com. 2008

literature survey

The comprehensive literature survey conducted in the frame of this project clearly revealed that the majority of all past research activities on ultrasound in suspensions focused on gaining a better understanding of

1. **the effects of US on the treated medium** in terms of
   - mechanical effects (particle breakage, debris detachment, fibre treatment, refining),
   - chemical effects.
2. **the role of process parameters on US effects** as a function of
   - frequency,
   - amplitude,
   - treatment time,
   - ambient pressure,
   - consistency.

literature survey – influence on ink detachment (I)



laser ink particles are effectively detached from fibre surfaces by US treatment

US treatment requires only small or moderate additional energy input for high increase in brightness

- **laser printed samples**
- **20 kHz piezo-electric**

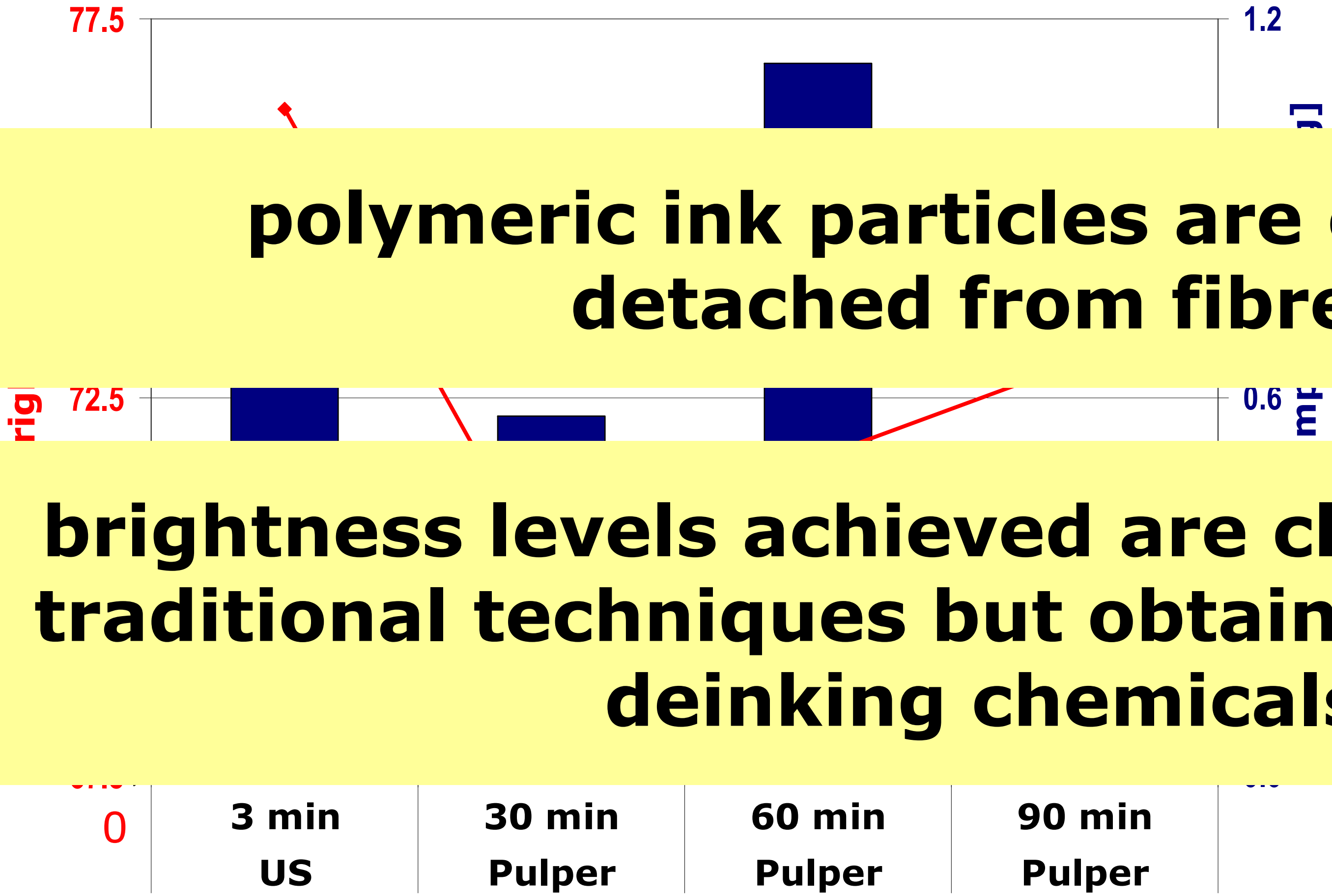
Deinking parameters

- washing

15 min,100 µm mesh

Source: Tatsumi, D., Higashihara, T., Kawamura, S., Matsumoto, T.: Ultrasonic treatment to improve the quality of recycled fibre pulp; Journal of Wood Science 46, 2000, p.405-409

literature survey – US influence on ink detachment (II)



- samples printed with high gloss polymeric ink

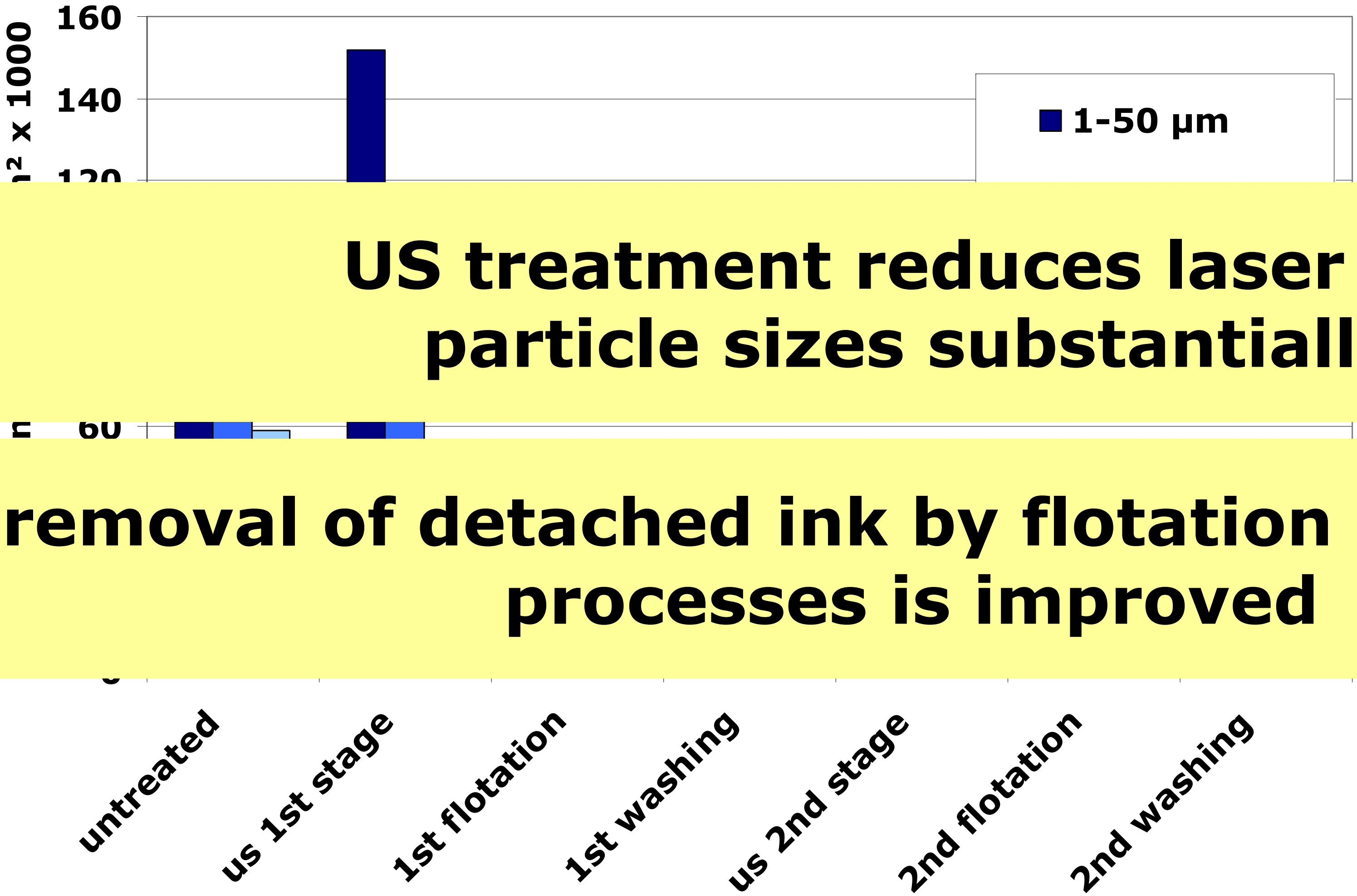
polymeric ink particles are efficiently detached from fibres

brightness levels achieved are close to those of traditional techniques but obtained without any deinking chemicals

- •NaPP 1.7%
- •NaMS 3.3%
- •Triton-X 0.1%

Source: L.L. Turai, C-H. Teng: Ultrasonic deinking of waste paper, Tappi Journal 61 (2), 31-34 (1978)

literature survey – US influence on particle breakage



- laser printed samples
- 47 kHz piezoelectric US
- batch-wise treatment

US treatment reduces laser ink particle sizes substantially

removal of detached ink by flotation and washing processes is improved

- dispersion agent Istemul-780

Source: R.C. Rogelio, R.Q. Juan, T.S. Jose: Deinking of Laser Printed Paper by Ultrasound, Flotation and Washing Systems, Progress in Paper Recycling 13 (2), 29-36 (2004)

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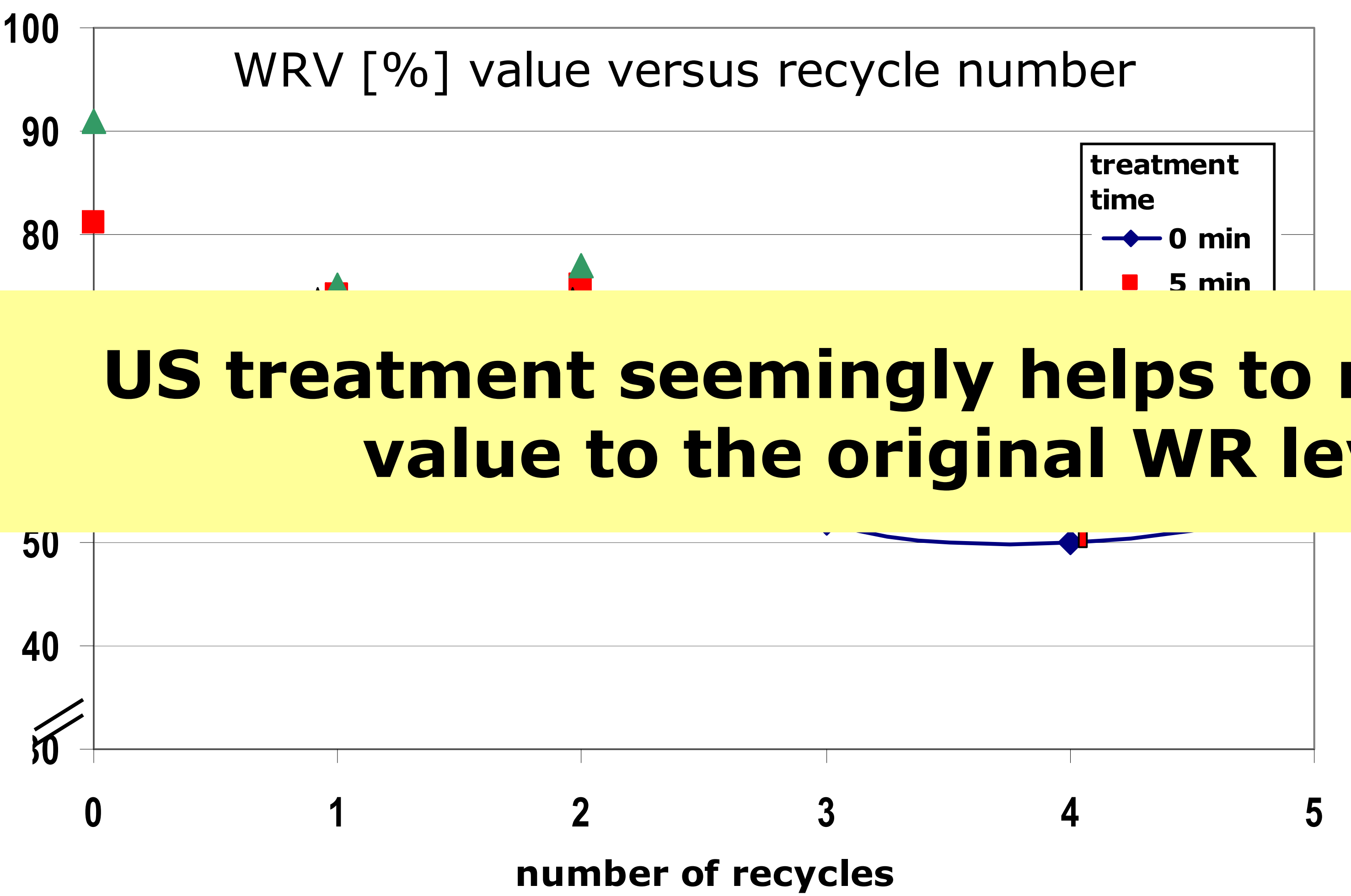
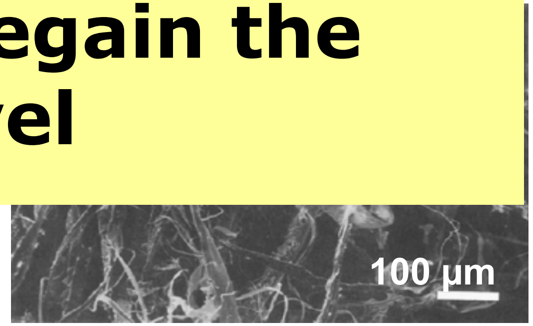
literature survey – US influence on fibre properties (I)

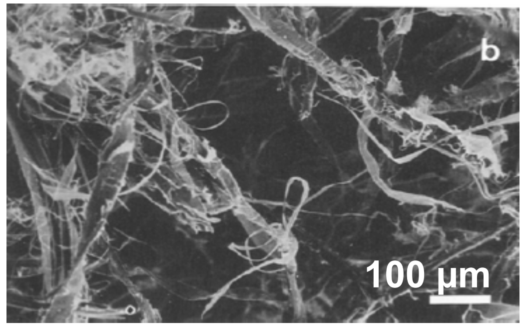


- **softwood fibres**
- **20 kHz piezoelectric US**
- **200 W electrical power input**
- **batch-wise treatment of 100 ml**
- **consistency 1%**

US treatment seemingly helps to regain the value to the original WR level



untreated pulp
(offset-printed newspaper)



10 min ultrasound

Source: Tatsumi, D., Higashihara, T., Kawamura, S., Matsumoto, T.: Ultrasonic treatment to improve the quality of recycled fibre pulp; Journal of Wood Science 46, 2000, p.405-409

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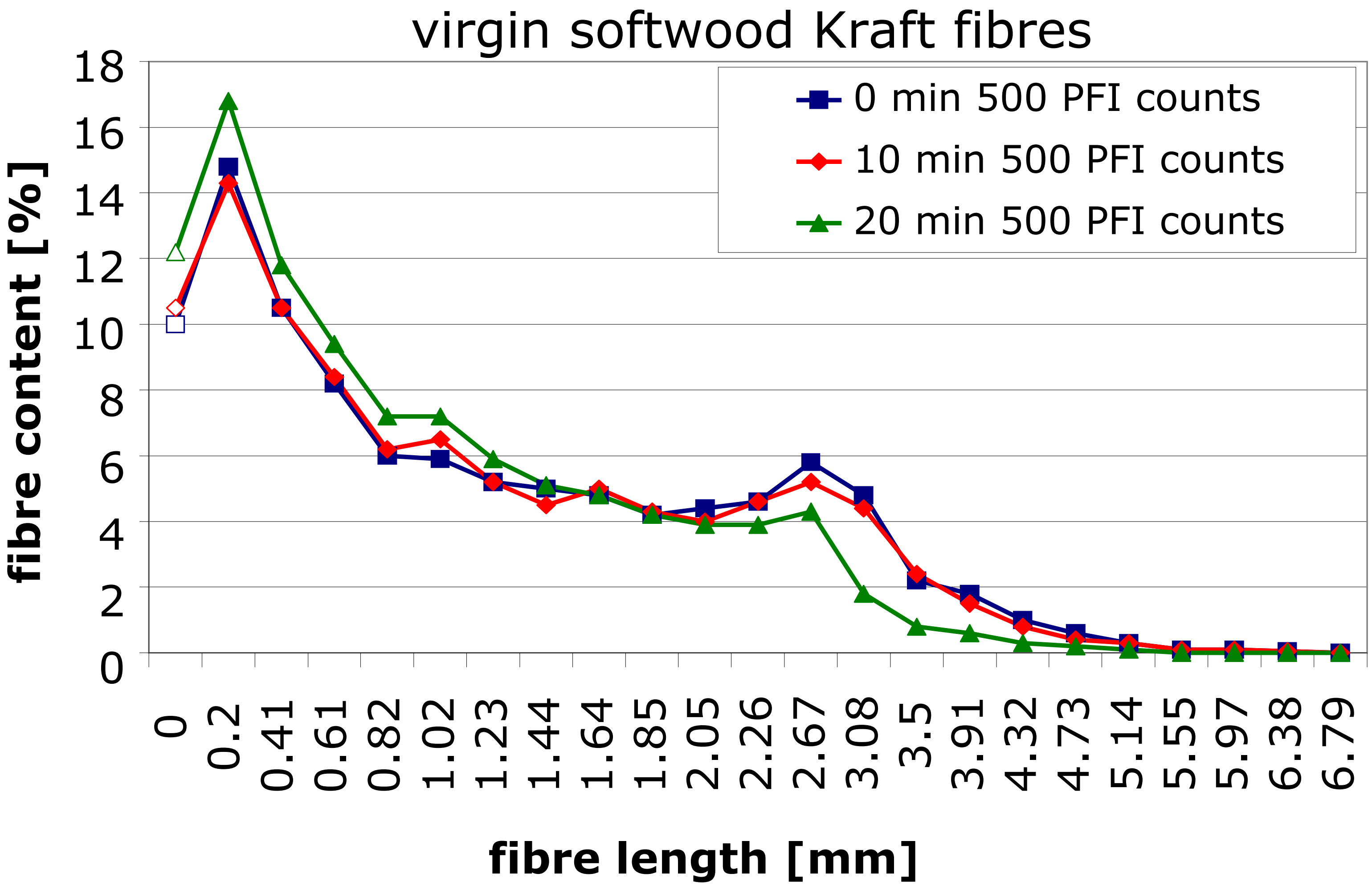
literature survey – US influence on fibre properties (II)



- **softwood fibres**
- **pre-treatment with PFI mill**
- **20 kHz piezoelectric US**
- **1000 W electrical power input**
- **batch-wise treatment**
- **consistency 1%**

Source: A. Manning, R. Thompson: The Influence of Ultrasound on Virgin Paper Fibres, Progress in Paper Recycling, 11 (4), 6-12 (2002)

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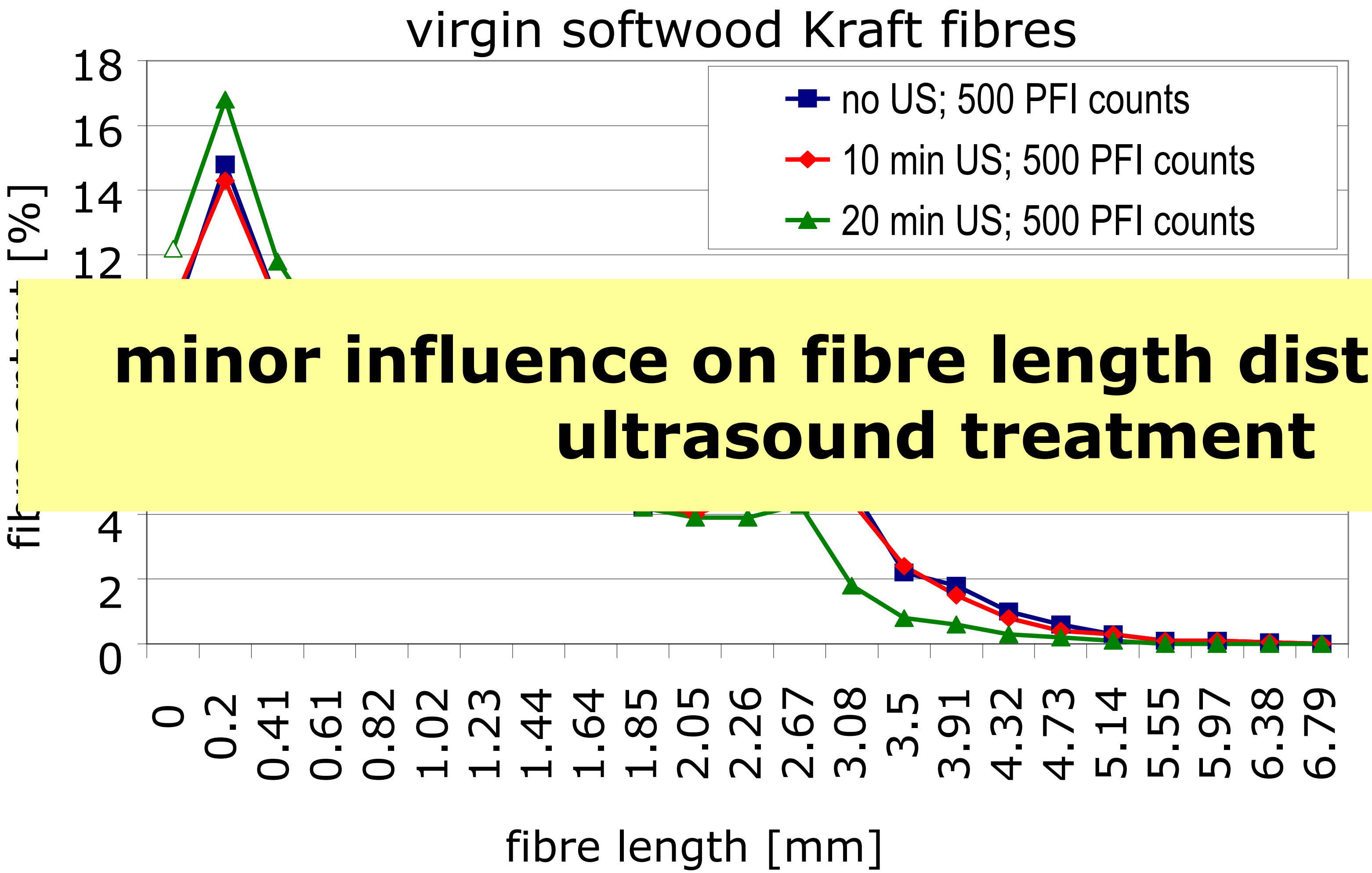
literature survey – influence on fibre properties (II)

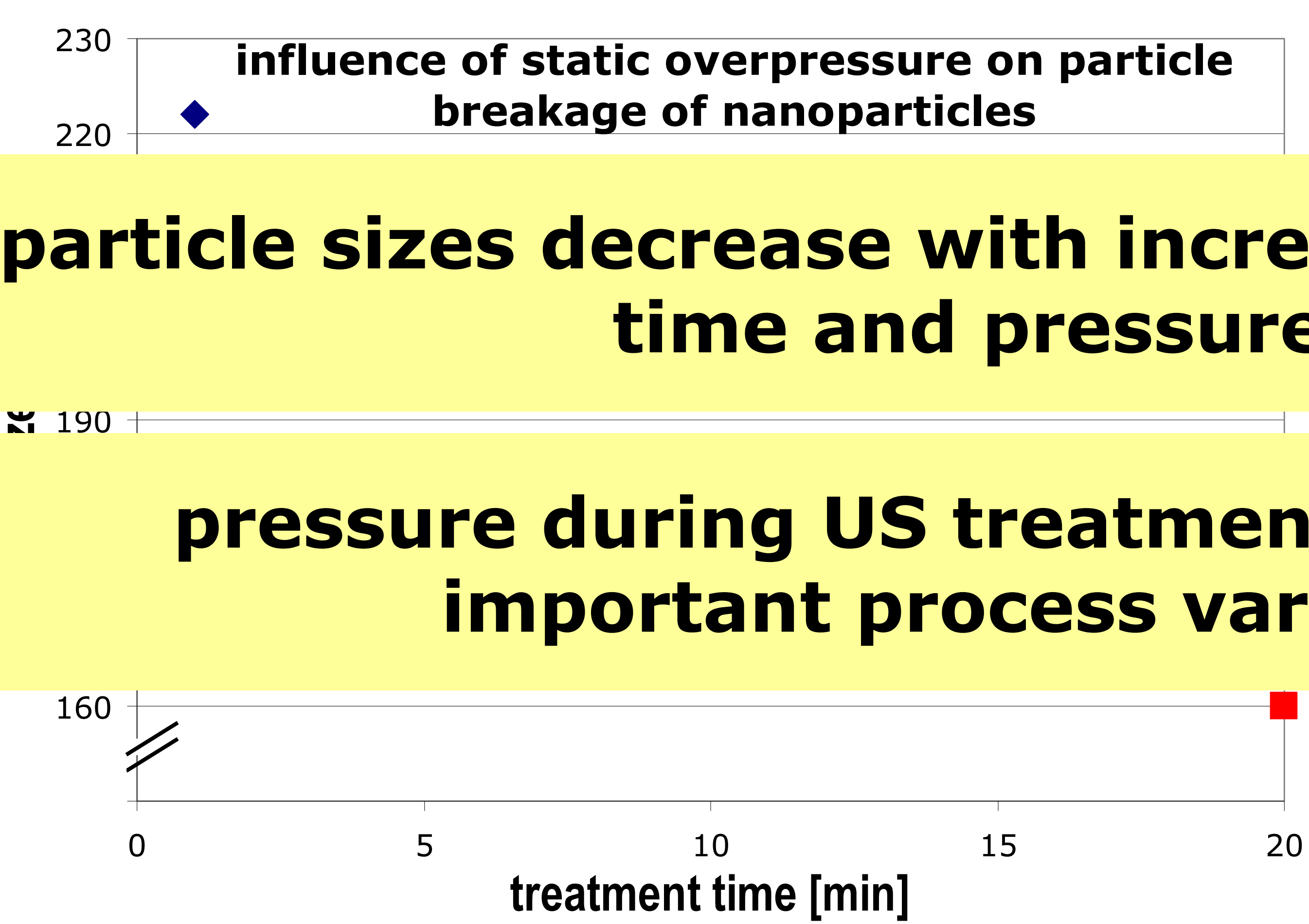


- softwood fibres
- pre-treatment with PFI mill
- 20 kHz piezoelectric US
- 1000 W electrical power input

minor influence on fibre length distribution by ultrasound treatment

Source: A. Manning, R. Thompson: The Influence of Ultrasound on Virgin Paper Fibres, Progress in Paper Recycling, 11 (4), 6-12 (2002)

literature survey – influence of static pressure



- treatment of nanoparticles SiO_2
- 20 kHz piezoelectric US (UIP

particle sizes decrease with increasing treatment time and pressure

pressure during US treatment is another important process variable

conclusions from the literature survey

- ink particles detachment and breakup is predominantly due to cavitation phenomena
- the intensity of cavitation is mainly influenced by
  - **the amplitude** of the US-waves (higher amplitudes lead to intensified cavitation)
  - **the static overpressure** prevailing in the reaction chamber (higher pressure intensify the collapse of cavitation bubbles and reduce the threshold for the appearance of cavitation)
- detachment and breakup of ink particles of cross-linked inks are improved
- detached particles' size can be reduced to floatable sizes
- ink removal of cross-linked inks can be improved
- savings in deinking chemicals are feasible
- certain fibre properties (WRV value) are partially regenerated

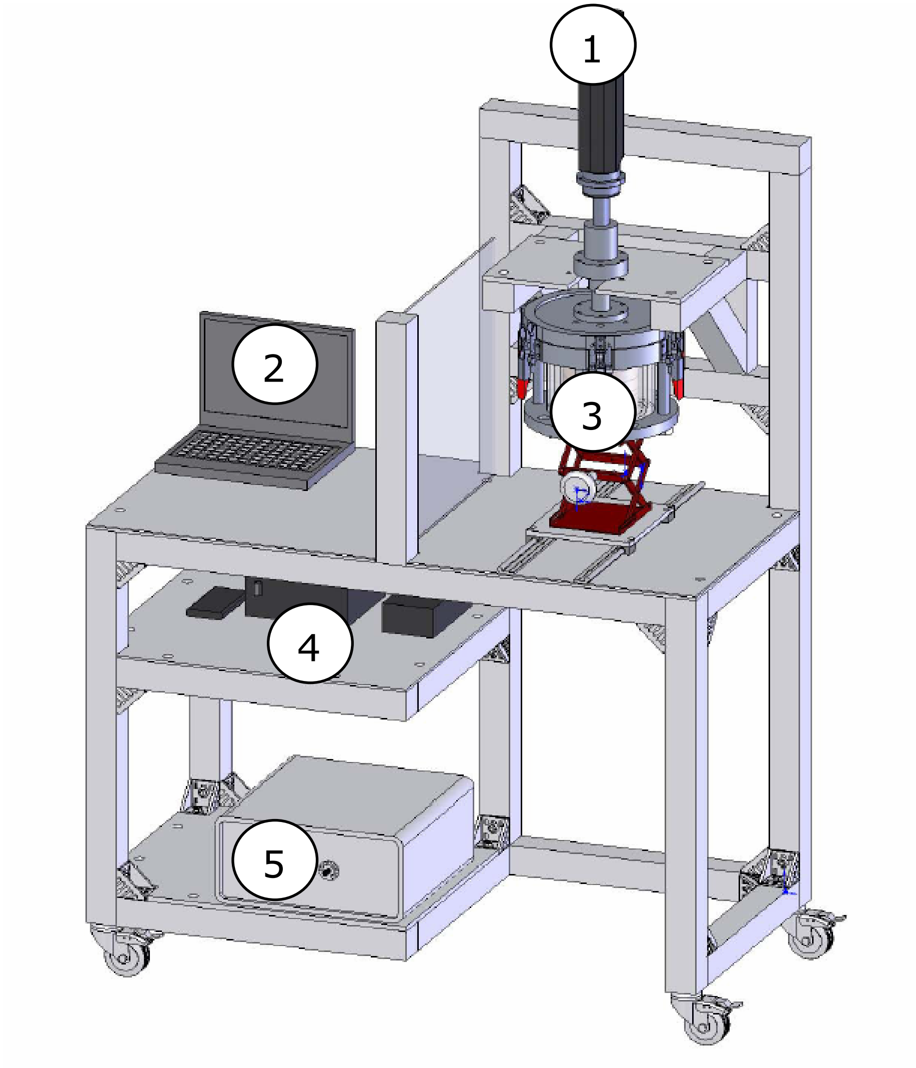
additional lab trials at Dresden University

- Focus on difficult to de-ink cross-linked printing inks
  - detachment and breakup
  - particles only poorly accessible by flotation or washing process

- cross-linked printing inks
  - toner inks (dry and liquid toner)
  - UV-cured inks

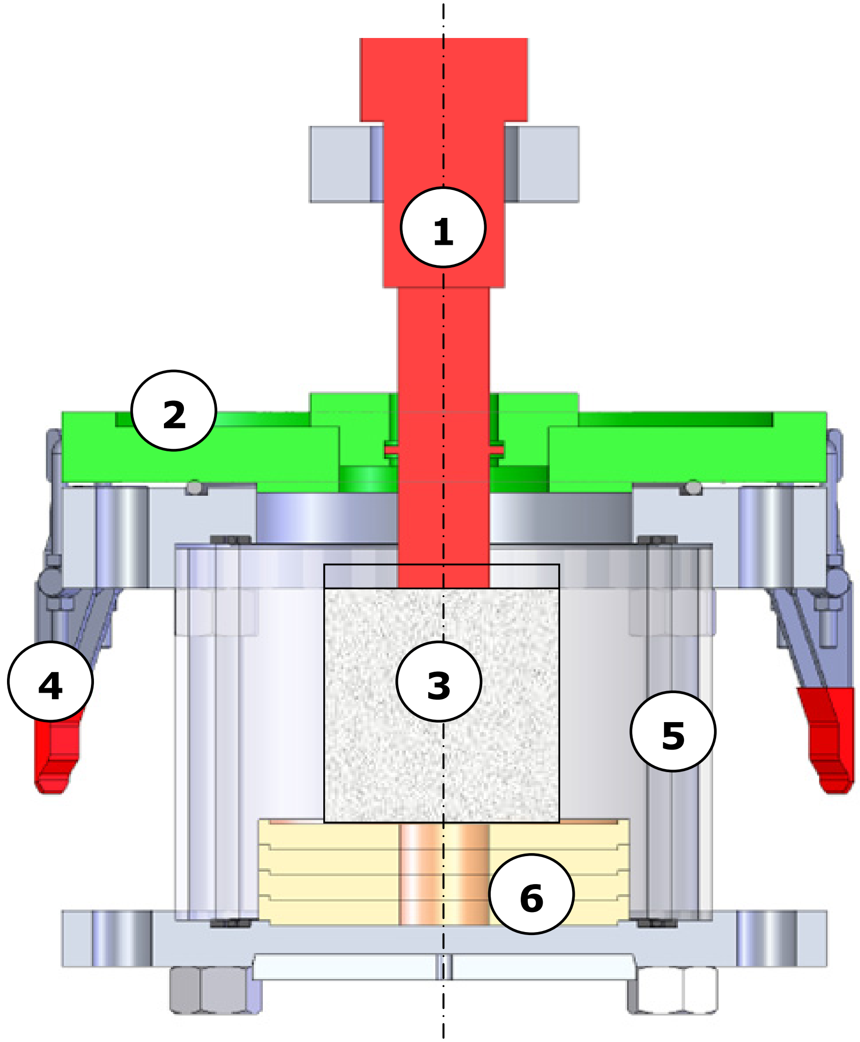
- choice of dry toner as an example of cross-linked ink
  - laser printed copy paper

available ultrasound equipment (I)



1. ultrasound converter with sonotrode
2. data acquisition and control of ultrasound generator by computer
3. pressure chamber for ultrasound treatment
4. equipment for measurement of energy consumption and temperature
5. ultrasound generator

available ultrasound equipment (II)



1. ultrasound booster and sonotrode
2. removable lid of the pressure chamber
3. test sample (fibre suspension in beaker 400 ml)
4. snapped closing of the lid
5. pressure chamber with glass casing (d=150 mm. h=150 mm. V=2.5 l)
6. spacer for adjustment of distance between sonotrode and bottom of beaker

experimental design (I)

- samples from laser printed copy paper
- experimental procedure on the basis of INGEDE Method 11
- US treatment before ink removal at 20 kHz, piezoelectric
- ink removal through washing instead of flotation
- use of PTS washing cell (5 min washing)
- use of dispersing agent (polysalt) instead of fatty acid
- additional trials without any deinking chemicals
- evaluation of handsheets (42,6 g/m²)
  - brightness (457 nm)
  - reflection factor (700 nm)
  - optical investigation (DOMAS dirt specs, particle size range)

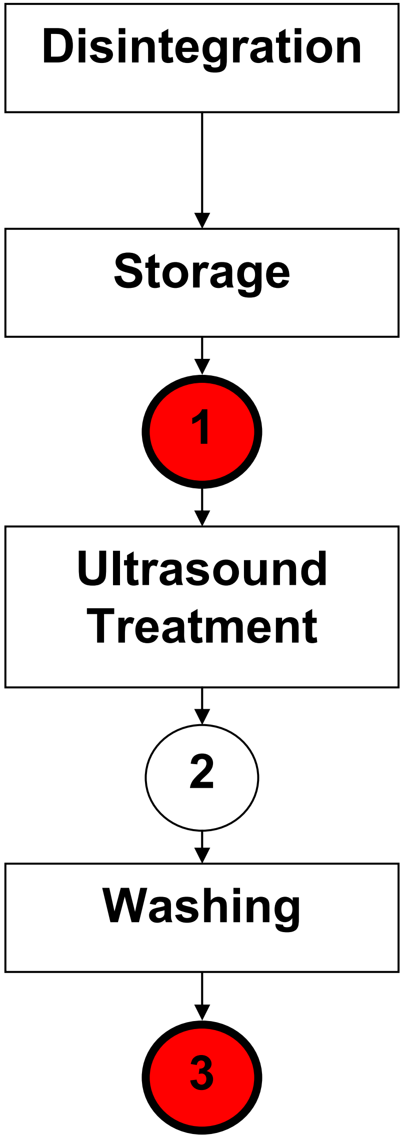
experimental design (II)

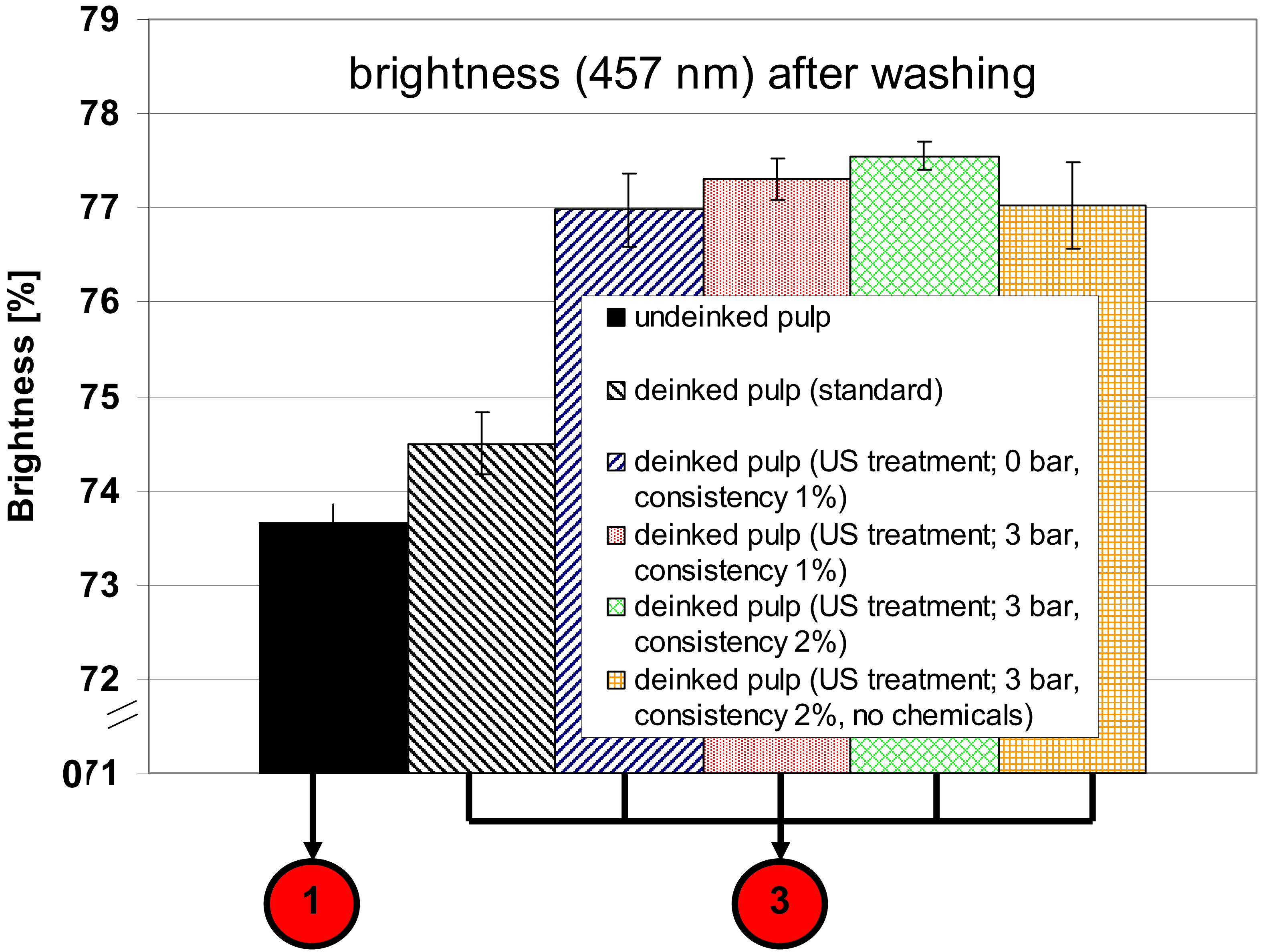
- process parameters varied

			overpressure		consistency	
trial	ultrasound treatment	deinking chemicals[1]	0 bar	3 bar	1 %	2 %
V1		x	x			
V2	x	x	x		x	
V3	x	x		x	x	
V4	x	x		x		x
V5	x			x		x

[1] 0.6 % NaOH (100%), 1.8% Sodium silicate (1.4-1.4 g/cm³), 0.7% H_2O_2 (100%), 0.8% Polysalt (50%)

results: brightness after washing (I)

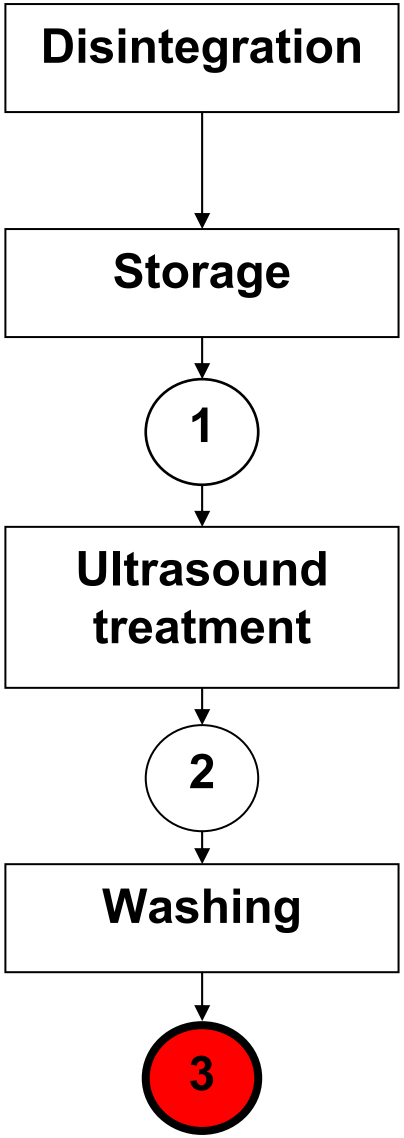


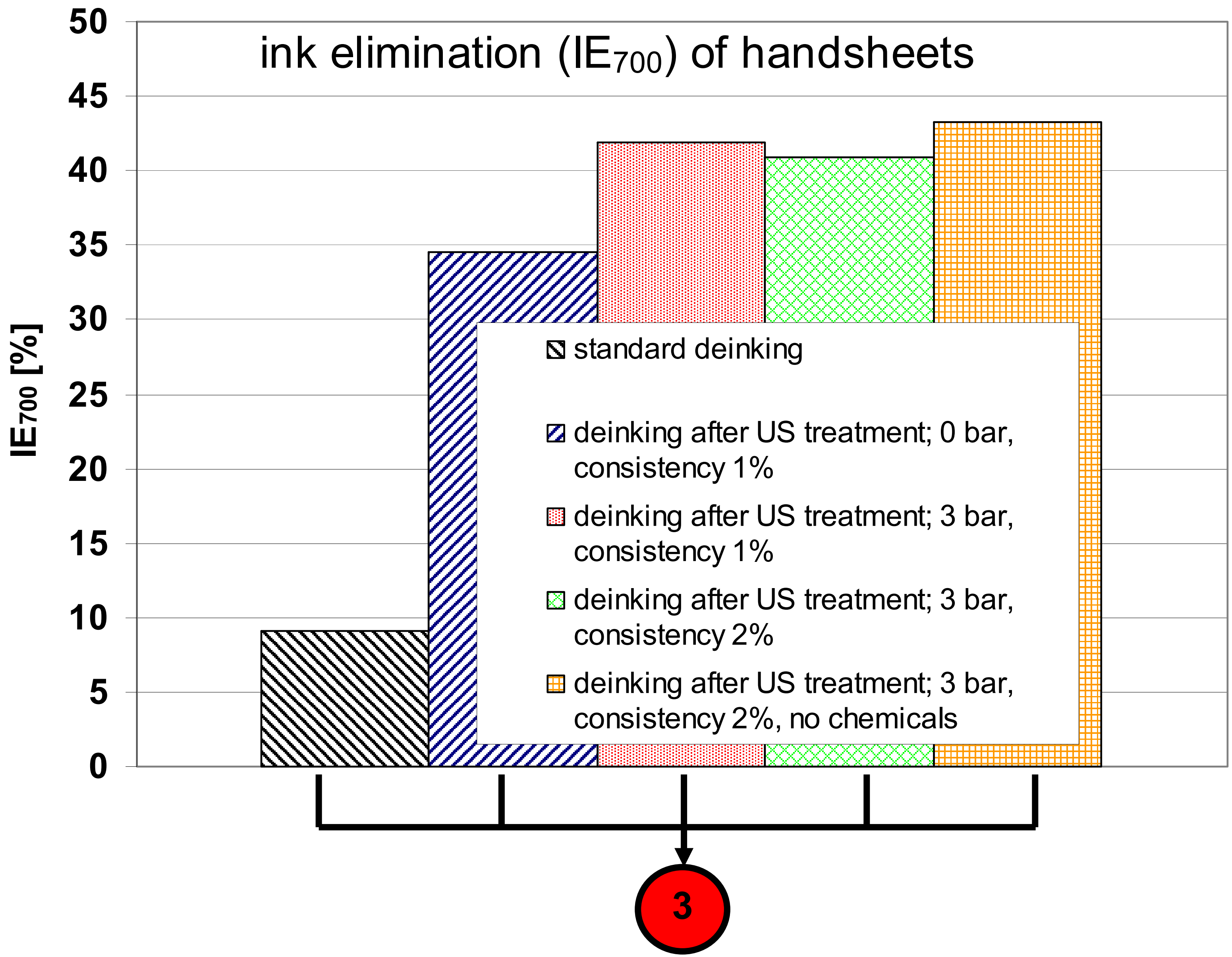


results: brightness after washing (II)

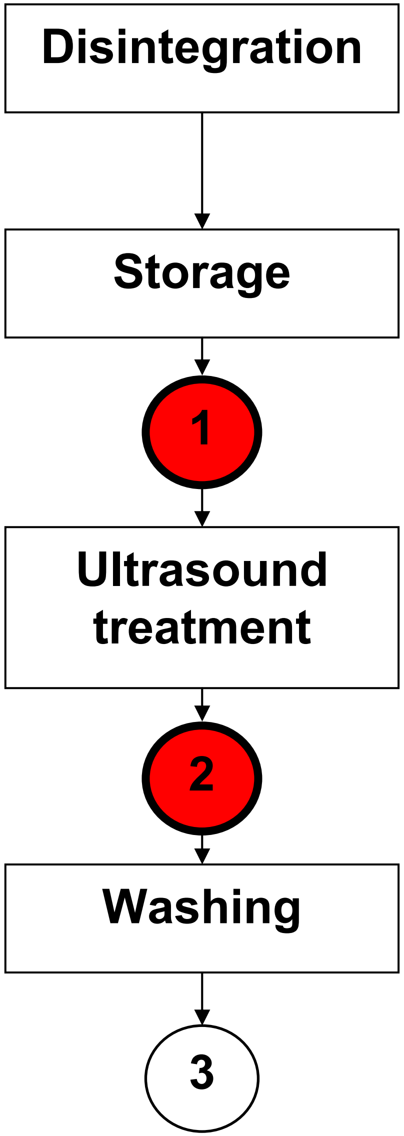
- up to 3 %-points higher brightness levels for all US-treated samples due to
  - improved detachment of ink particles from laser printed paper by ultrasound treatment
- slight improvement of brightness at higher pressure due to
  - an intensified generation of cavitation bubbles close to the fibres
  - improved ink detachment
- similar brightness level in the absence of deinking chemicals
- no decrease in brightness at higher consistency of 2 %
  - comparable detachment of ink particles from laser printed paper
  - reduction of specific energy consumption of ultrasound treatment

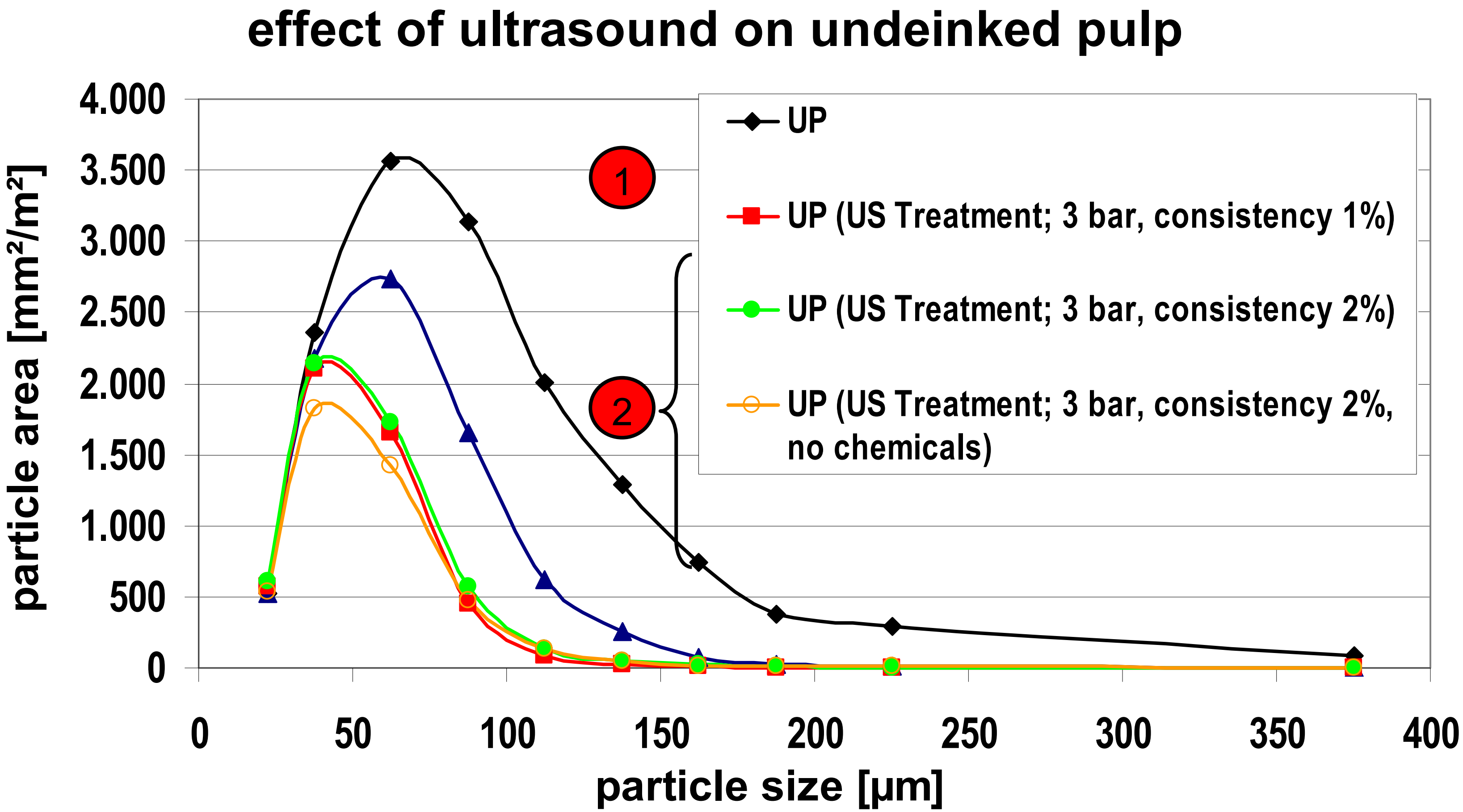
results: Ink elimination after washing



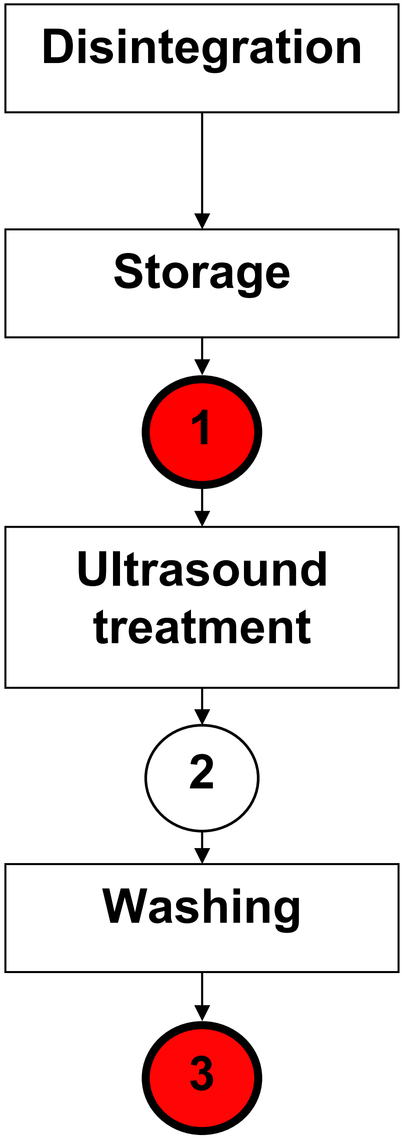


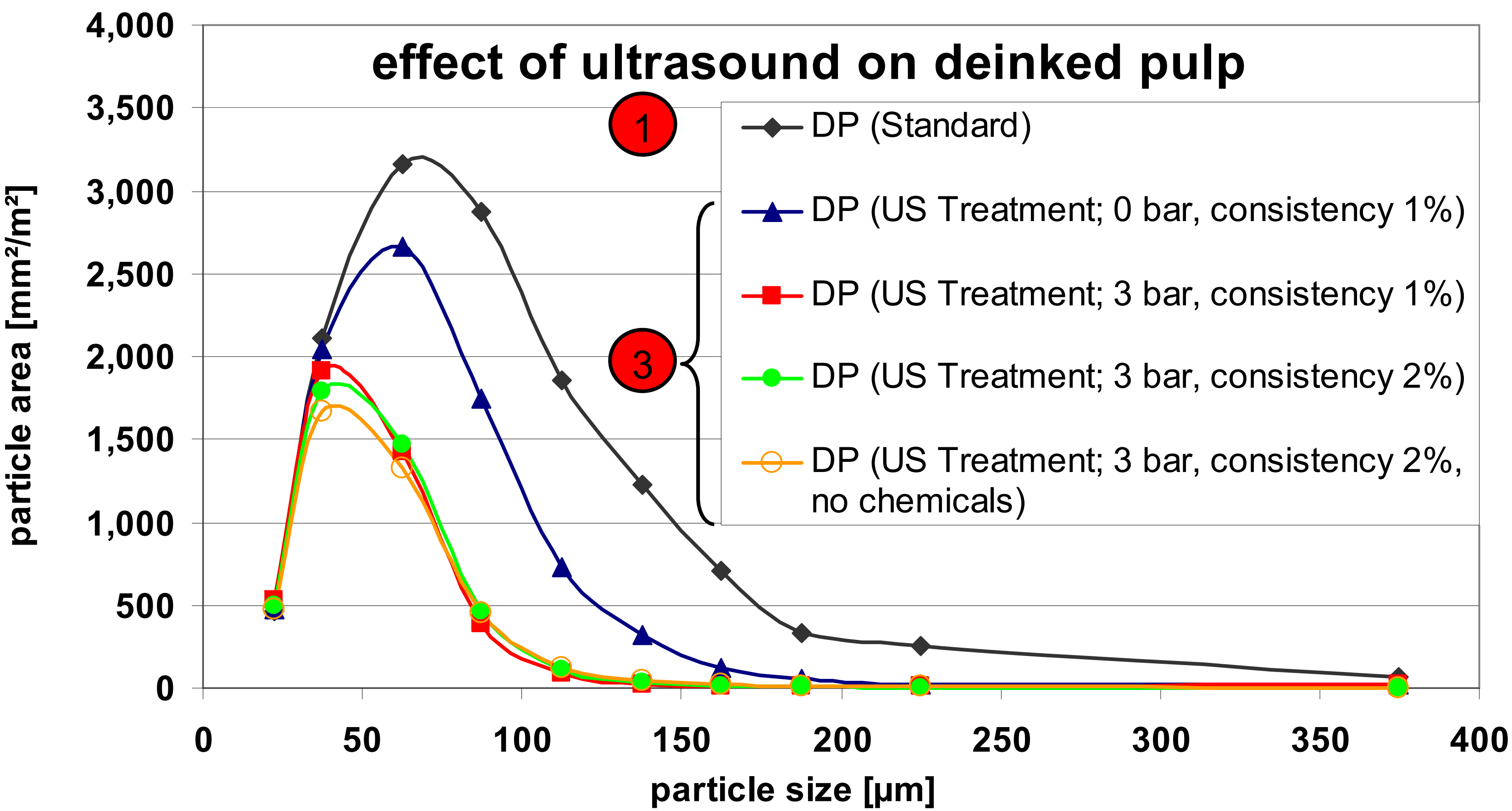
results: particle area after US treatment





results: particle area after washing





summary of laboratory results (I)

- reduction of particle size (area) for all US treated samples but slight increase in particle area in the lower particle size range due to additional break-up of ink particles and break-up of larger particles by ultrasound treatment
- additional decrease of particle area at higher pressure level
- intensified generation of cavitation bubbles close to fibres improves particle break-up
- comparable reduction of particle area without deinking chemicals
- effect of ultrasound independent from chemicals
- increased brightness for US treated laser printed samples
- comparable brightness levels with and without use of chemicals
- comparable brightness levels at consistencies of 1% and 2%
- further reduction of particle area at higher pressure

conclusions from laboratory trials

- US has the potential to improve the detachment of ink particles from laser printed samples (cross-linked printing ink)

- US treatment leads to an improved break-up of ink particles from laser printed samples

- with US both the detachment and the breakup of ink particles from laser printed samples is possible without the help of deinking chemicals

open questions

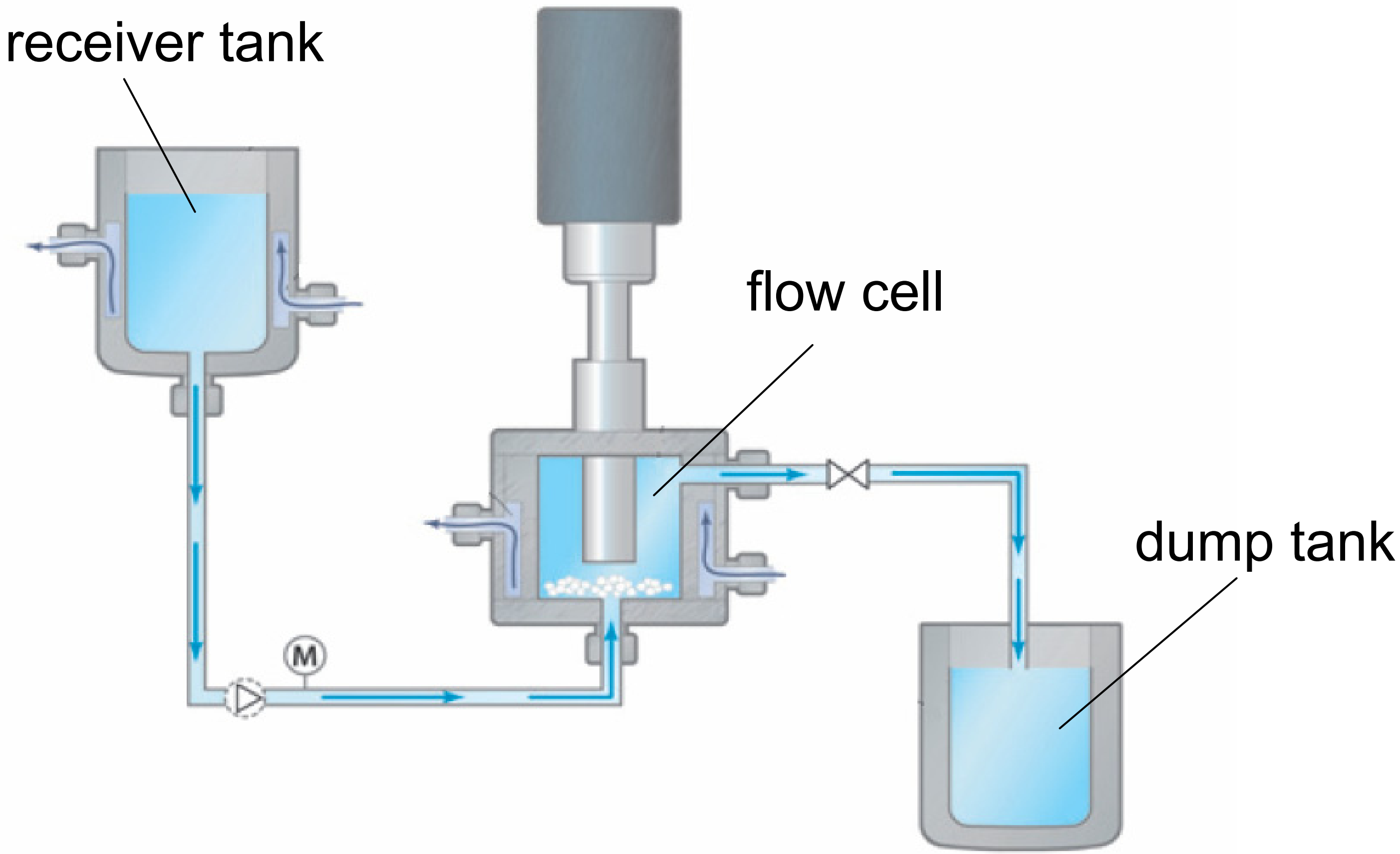
- How high would the specific energy consumption be in an industrial application?
- Is it possible to reach equally promising results with standard deinking grades in standard flotation processes
  - at reduced ultrasound amplitudes in order to decrease energy consumption and material erosion,
  - at increased consistencies in order to decrease specific energy consumption,
  - at higher overpressure in the reaction chamber with an improved experimental design to increase energy transfer into the medium to be treated(increase of ink detachment and break-up),
  - at reduced treatment times to decrease energy consumption and to allow for continuous treatment,
- Whitch results are achievable with other cross-linked printing inks (UV-cured inks, liquid toner)?

open questions

- How does the ratio of the diameters of sonotrode and beaker (d/D ratio) affect the results?
- Can the results be further improved by an optimised experimental design which allows the generation of a stationary wave in the treated suspension?
- How can the material erosion of the sonotrode be reduced?
- What results will be achieved at US frequencies others than those studied in the past (including the combination of two or more ultrasound sources)?
- Is it possible to reach comparable results with continuous treatment?

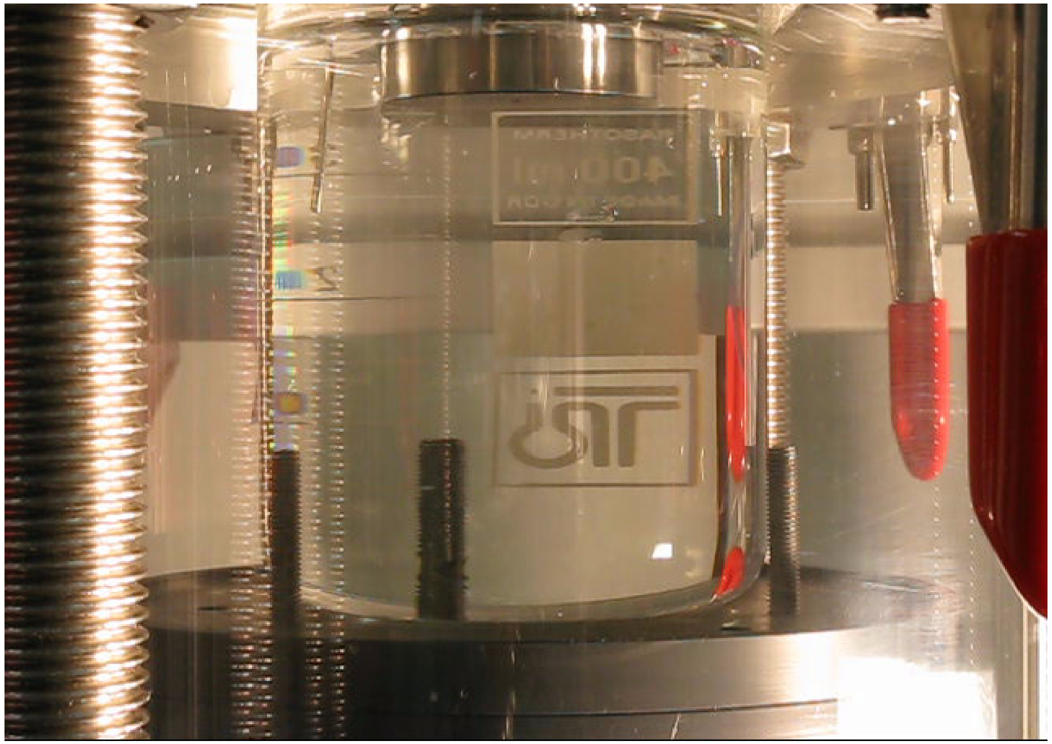
future prospects

- Installation of a new test rig for continuous operation in Q1/2009



future prospects

- start of a new project in 2009 to improve fibre properties by ultrasound treatment



Thanks for sharing
these ideas with us