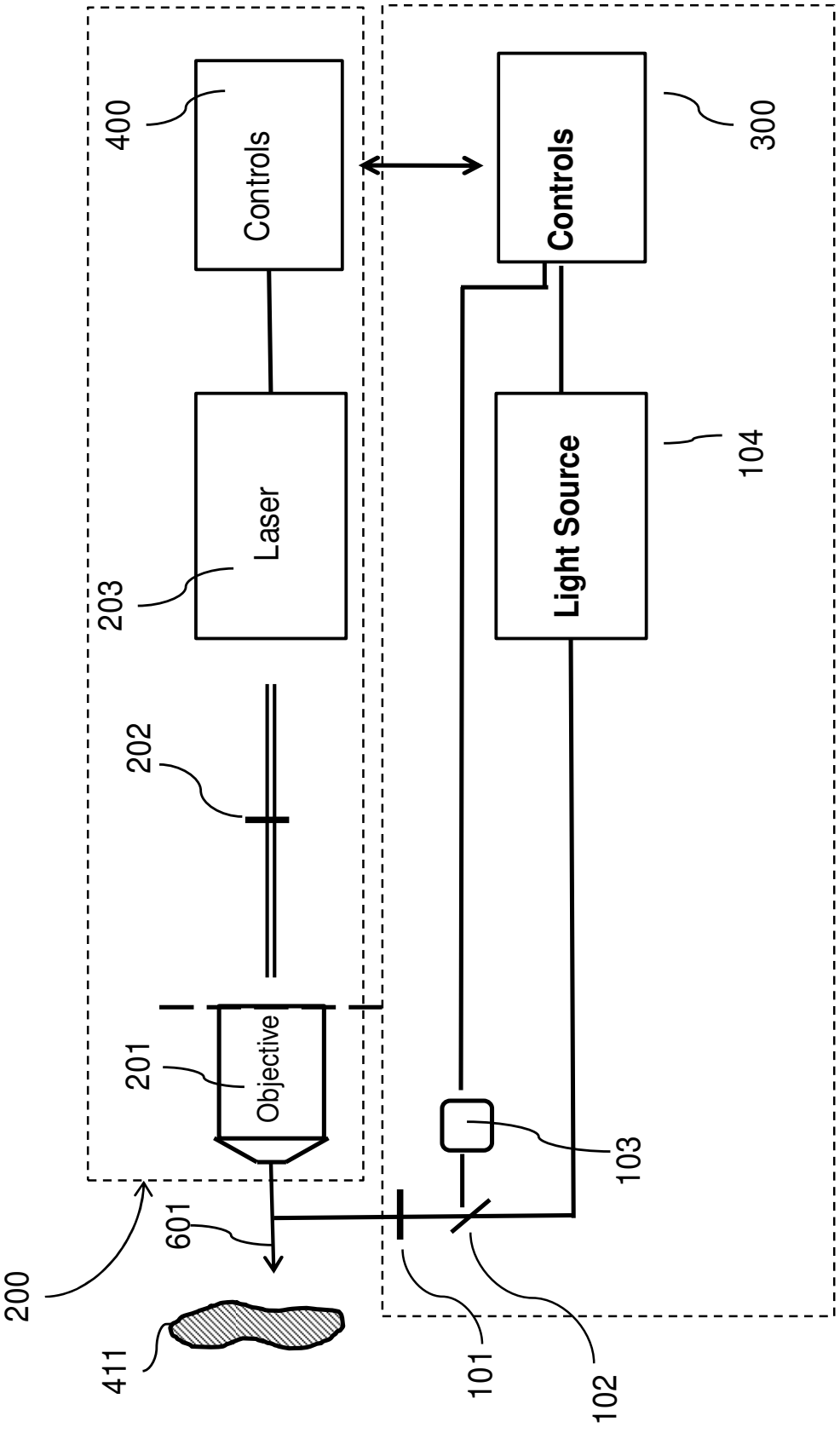

400
Controls
300
Controls
203
Laser
104
Light Source
202
201
Objective
103
601
200
411
101
102
100

Figure 1

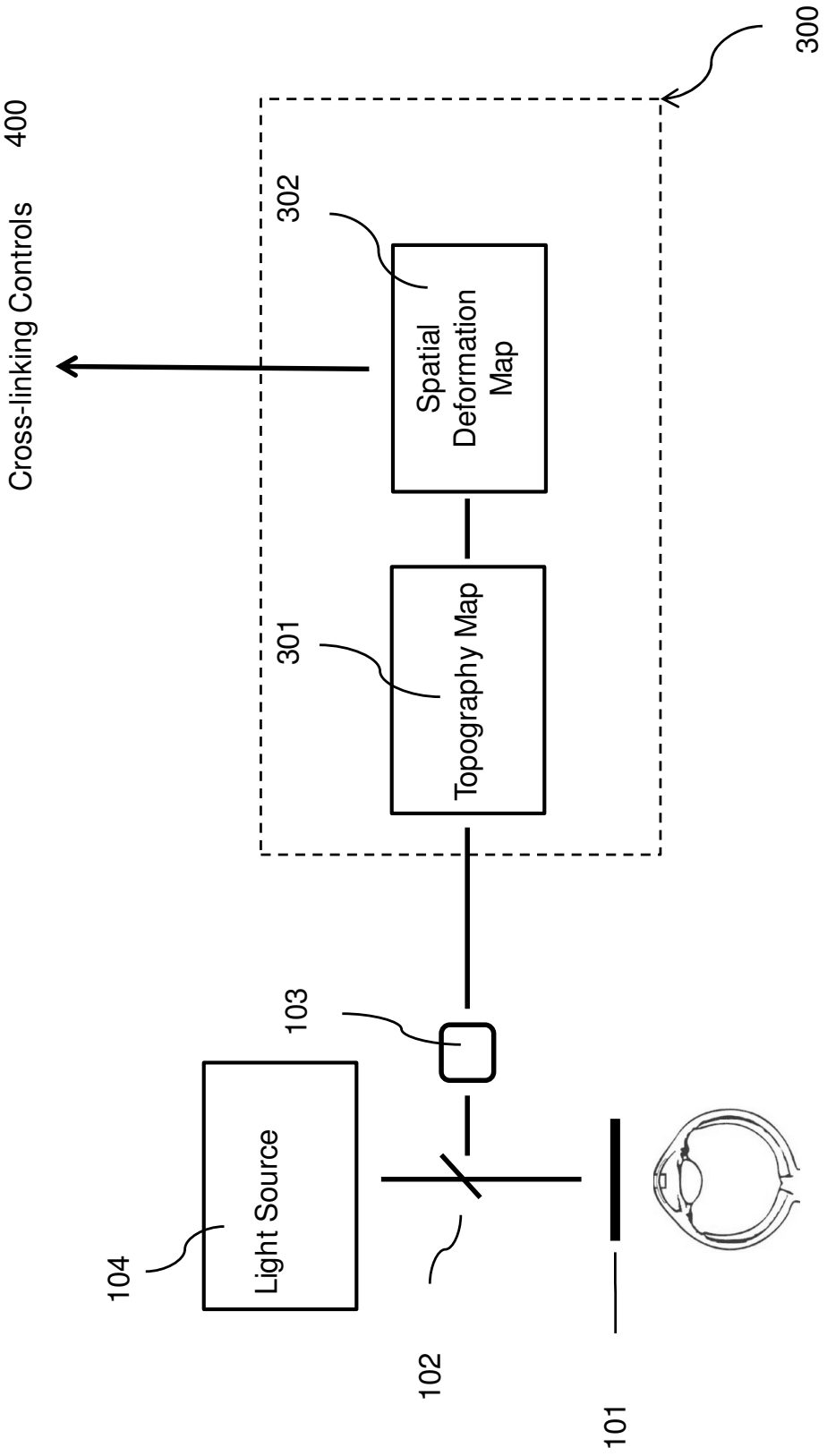

300
400
Cross-linking Controls
302
Spatial Deformation Map
301
Topography Map
103
104
Light Source
102
101

Figure 2

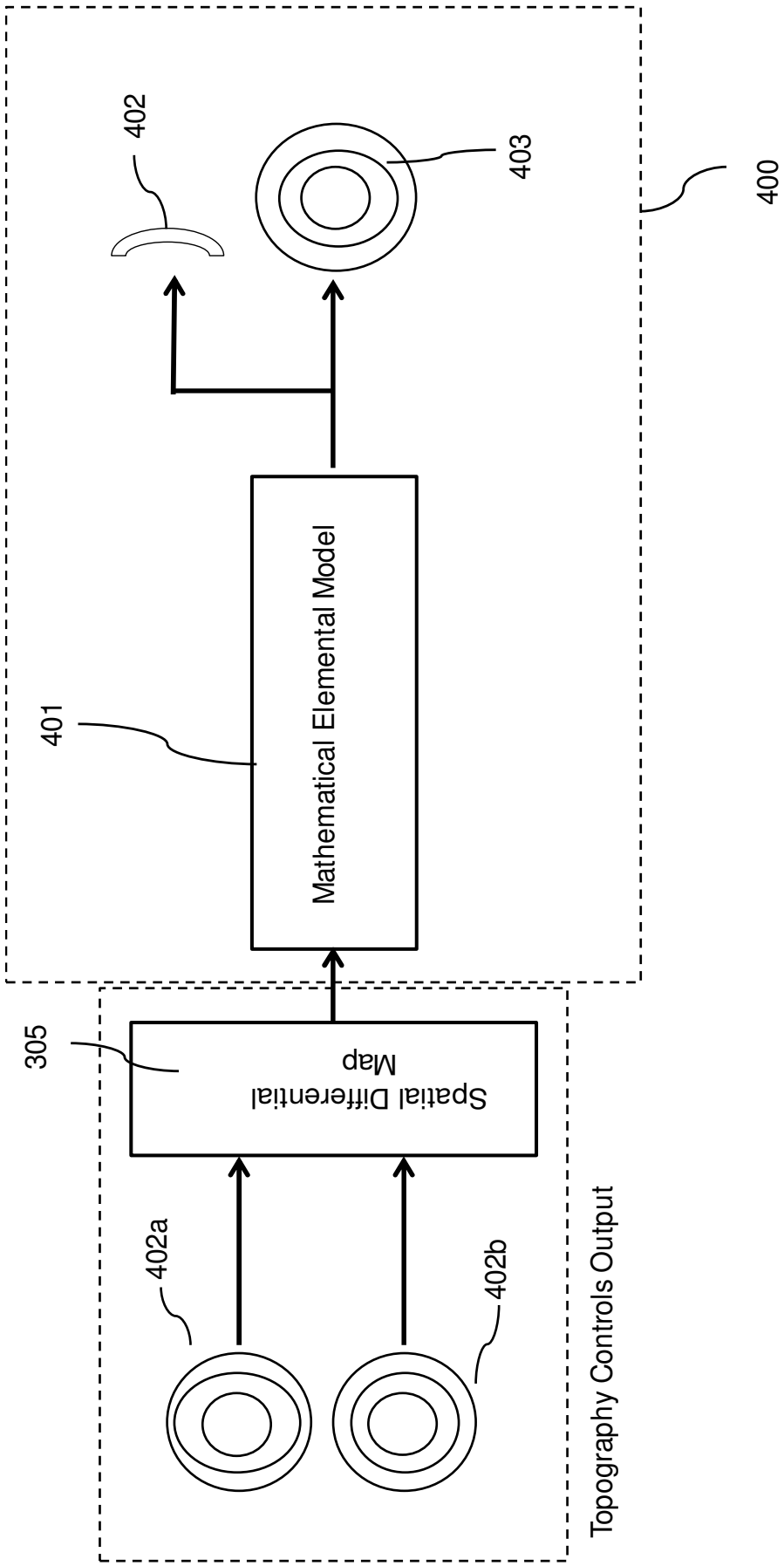

402
403
400
401
Mathematical Elemental Model
305
Spatial Differential Map
402a
402b
Topography Controls Output

Figure 3

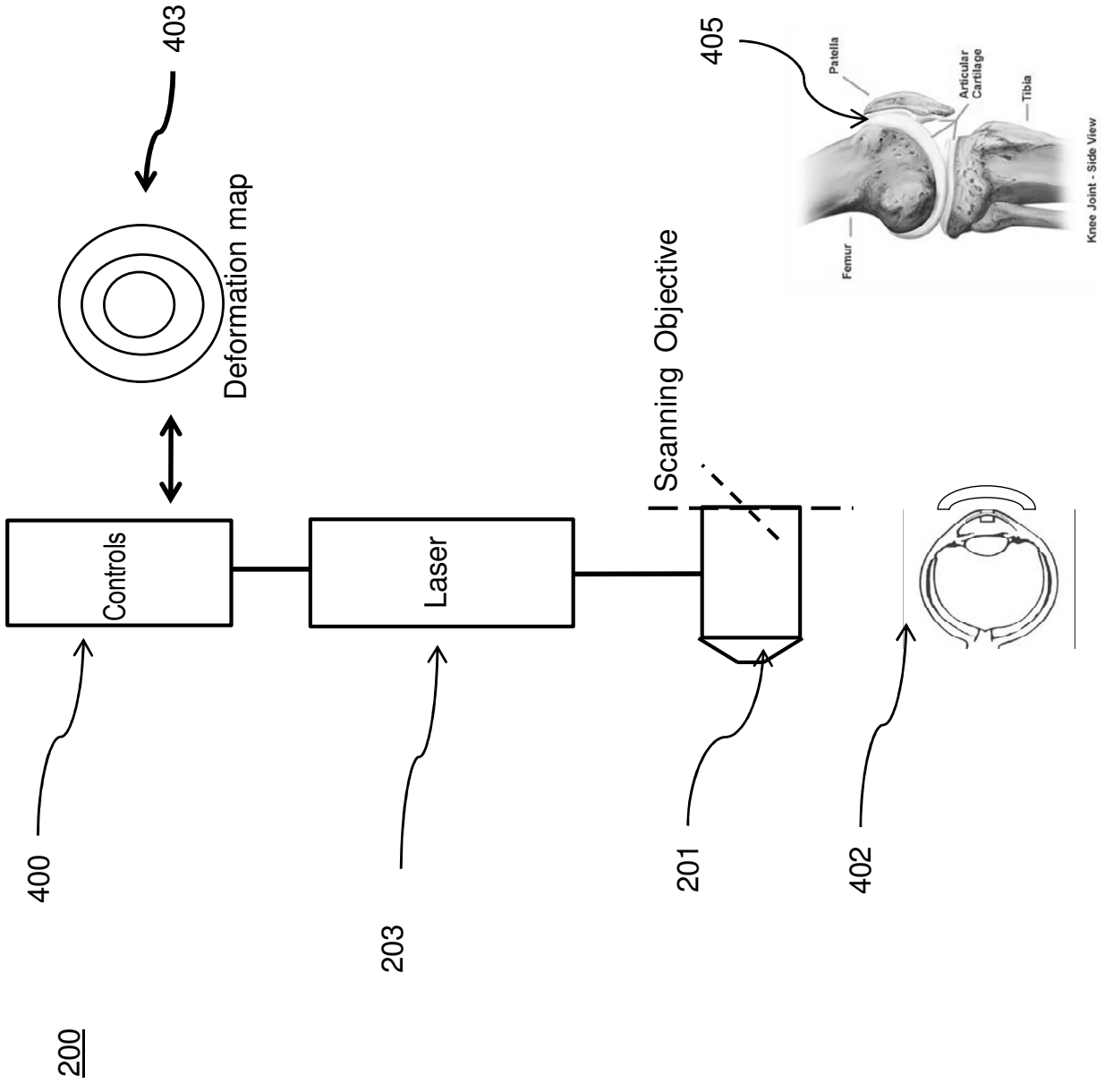

200
403
Deformation map
Controls
Laser
Scanning Objective
405
Patella
Articular Cartilage
Tibia
Femur
Knee Joint - Side View
400
203
201
402

Figure 4

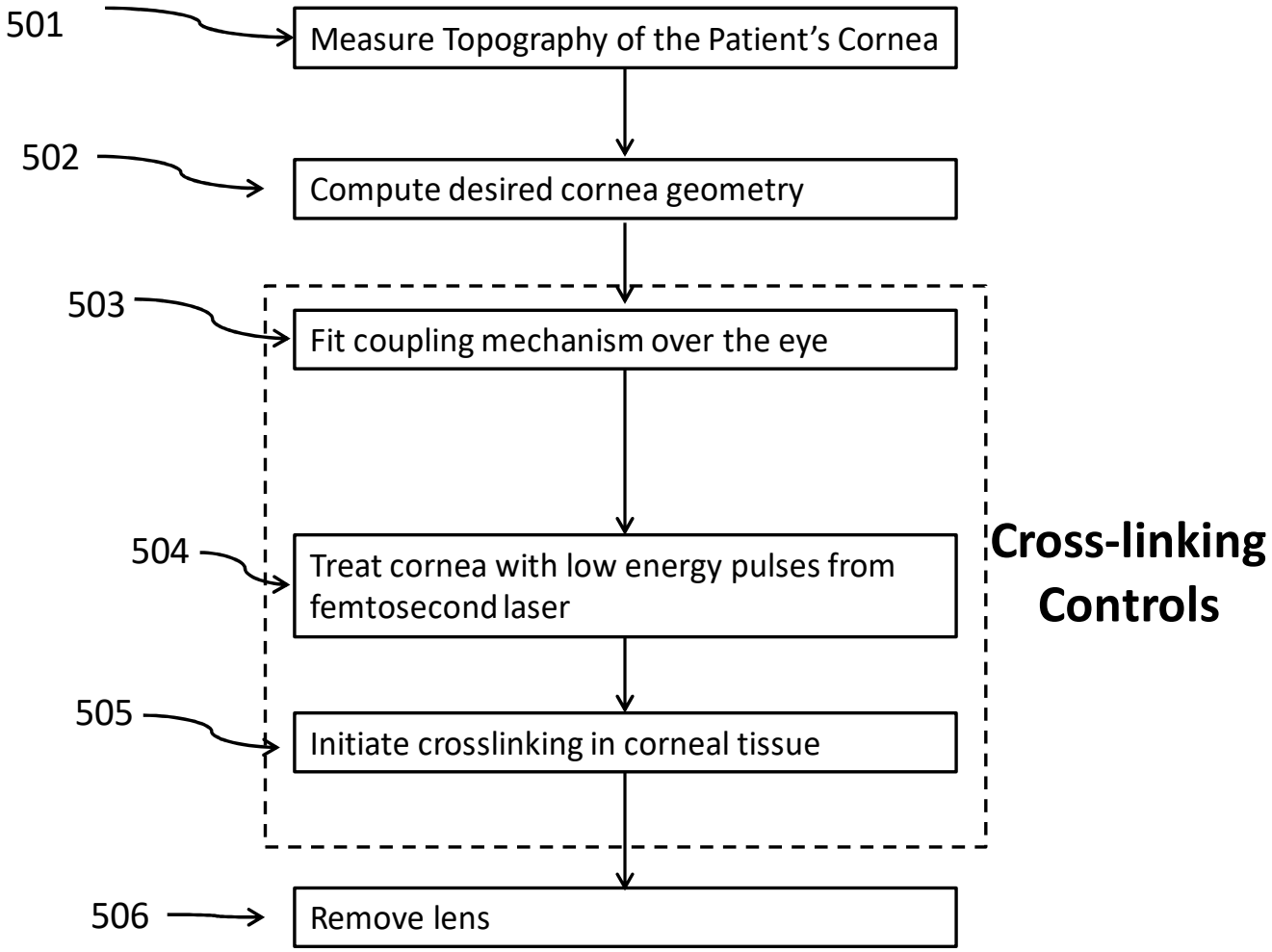

501
Measure Topography of the Patient's Cornea
502
Compute desired cornea geometry
503
Fit coupling mechanism over the eye
504
Treat cornea with low energy pulses from femtosecond laser
505
Initiate crosslinking in corneal tissue
506
Remove lens
Cross-linking Controls

Figure 5A

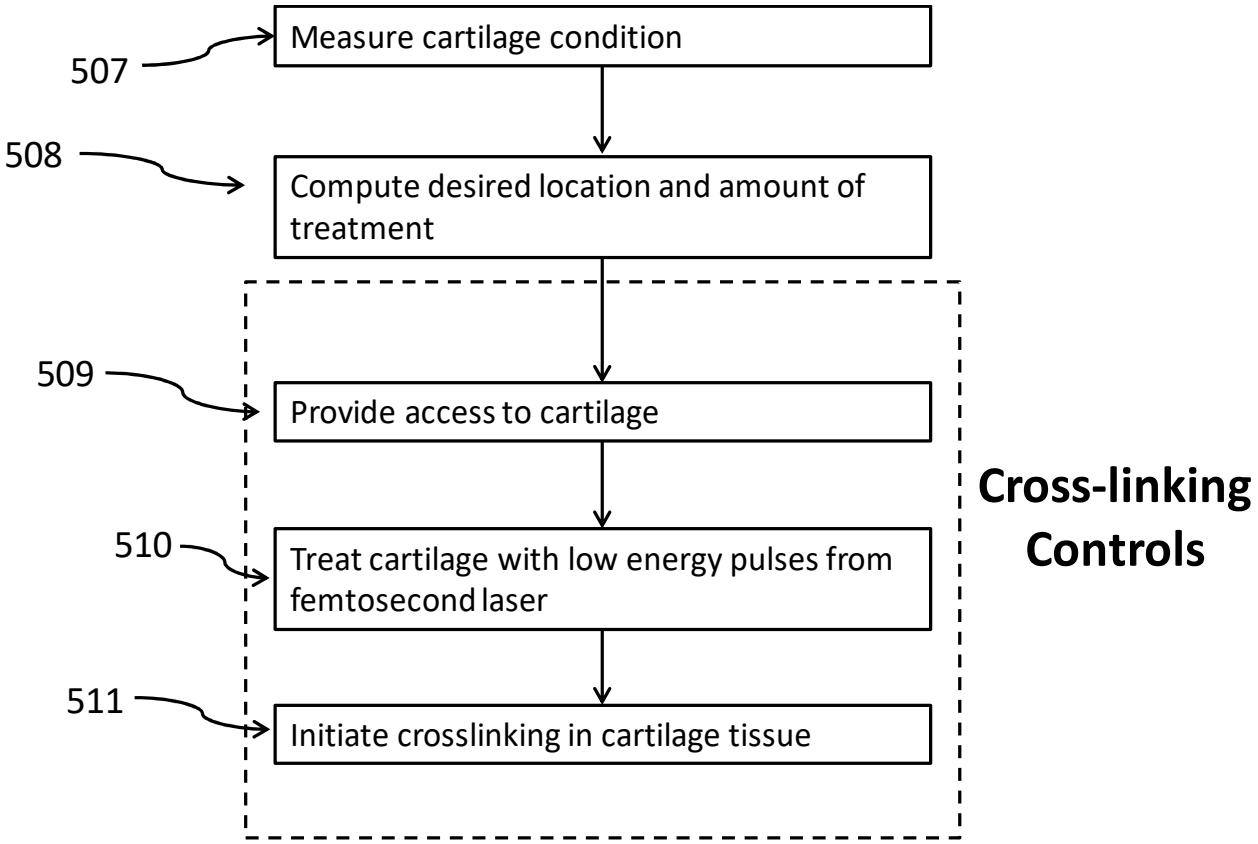

Measure cartilage condition
507
508
Compute desired location and amount of treatment
509
Provide access to cartilage
510
Treat cartilage with low energy pulses from femtosecond laser
511
Initiate crosslinking in cartilage tissue
Cross-linking Controls

Figure 5B

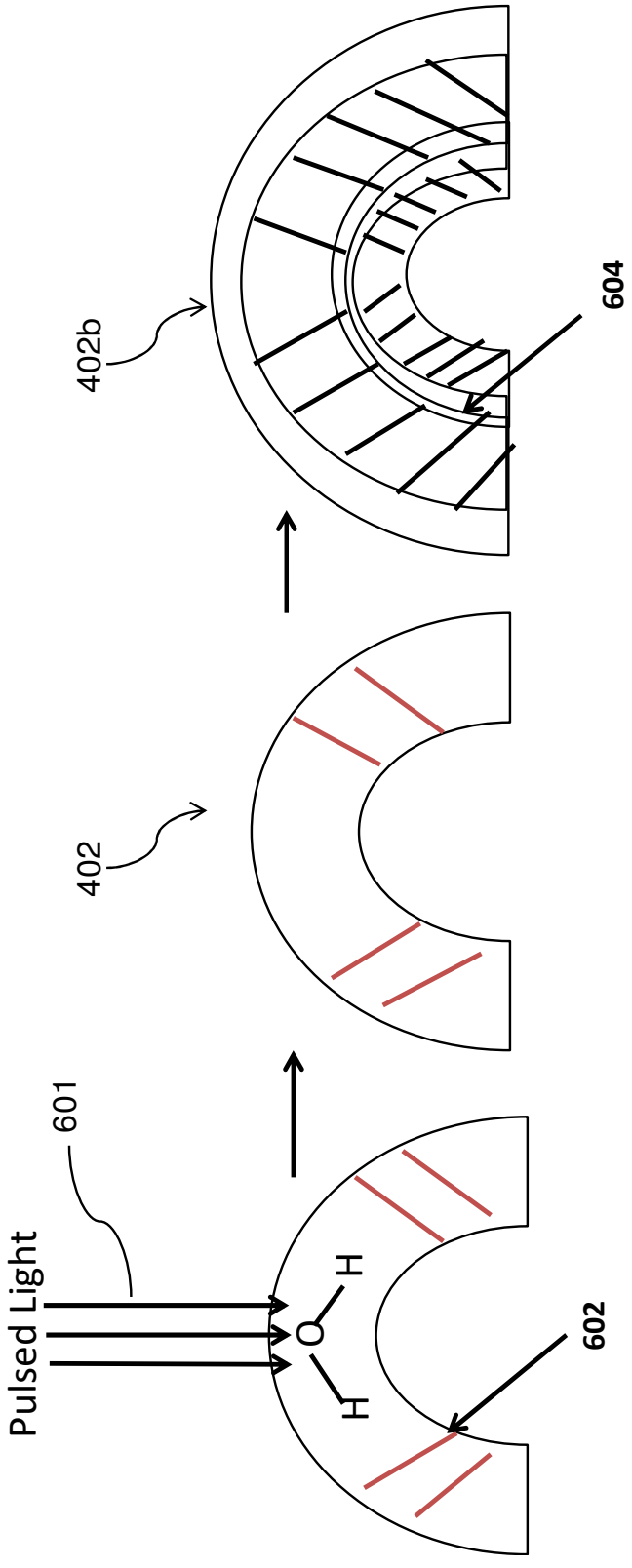


Figure 6

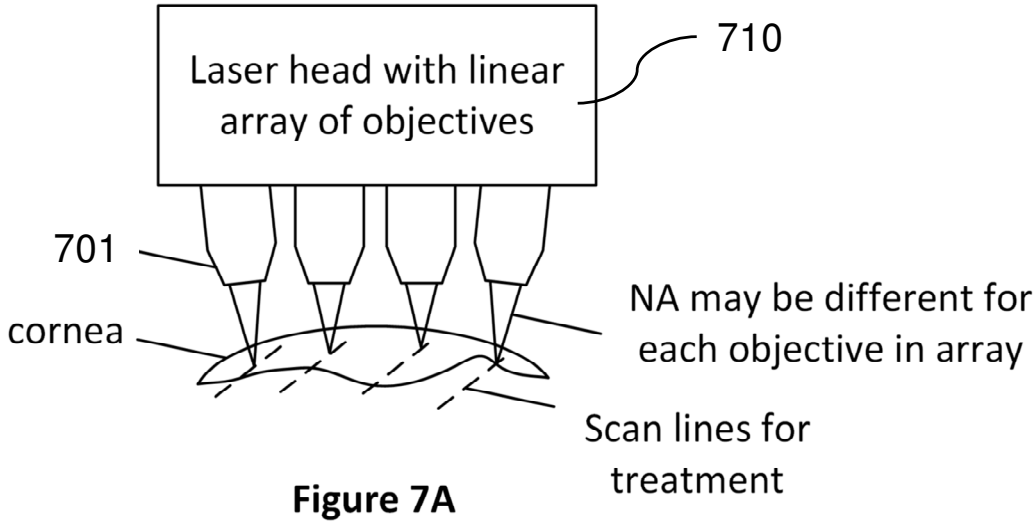


Figure 7A

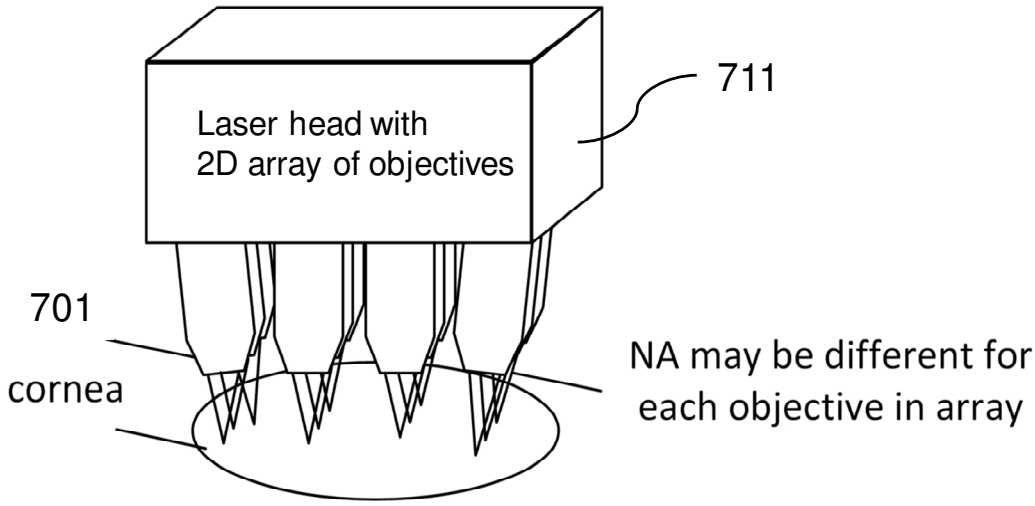


Figure 7B

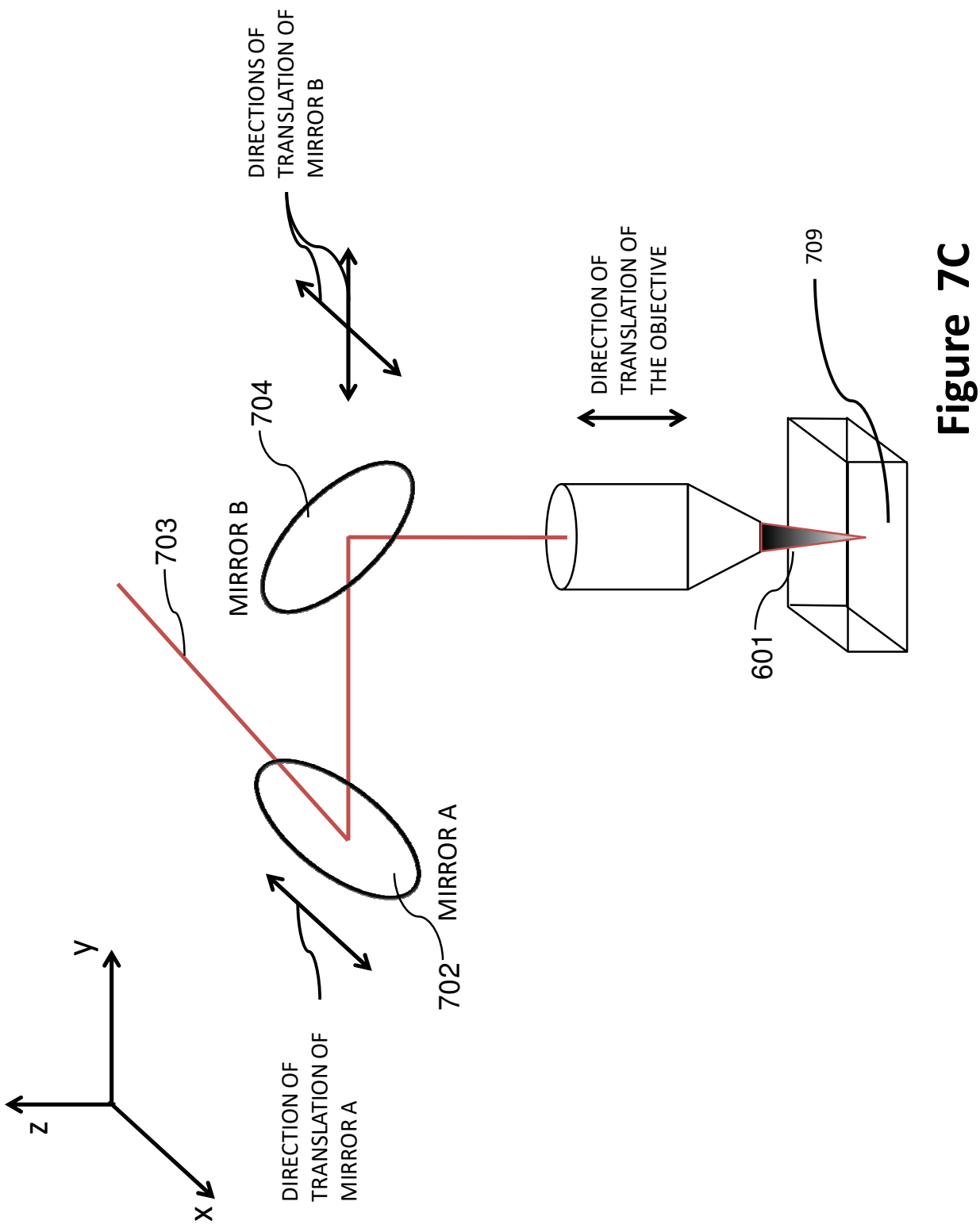

DIRECTIONS OF TRANSLATION OF MIRROR B
704
MIRROR B
703
DIRECTION OF TRANSLATION OF THE OBJECTIVE
709
601
MIRROR A
702
DIRECTION OF TRANSLATION OF MIRROR A
y
z
x

Figure 7C

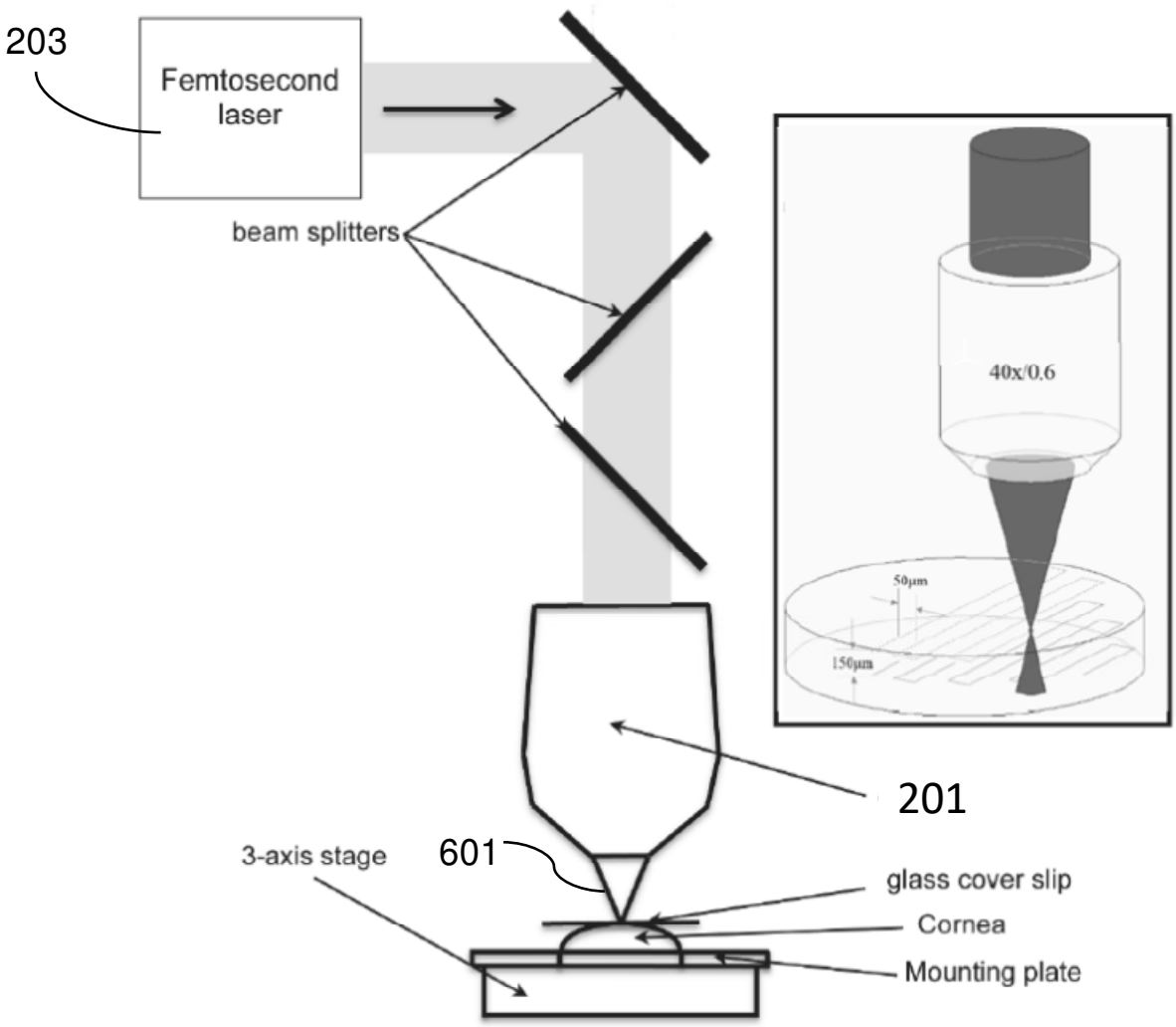

203
Femtosecond laser
beam splitters
40x/0.6
50μm
150μm
201
3-axis stage
601
glass cover slip
Cornea
Mounting plate

Figure 8

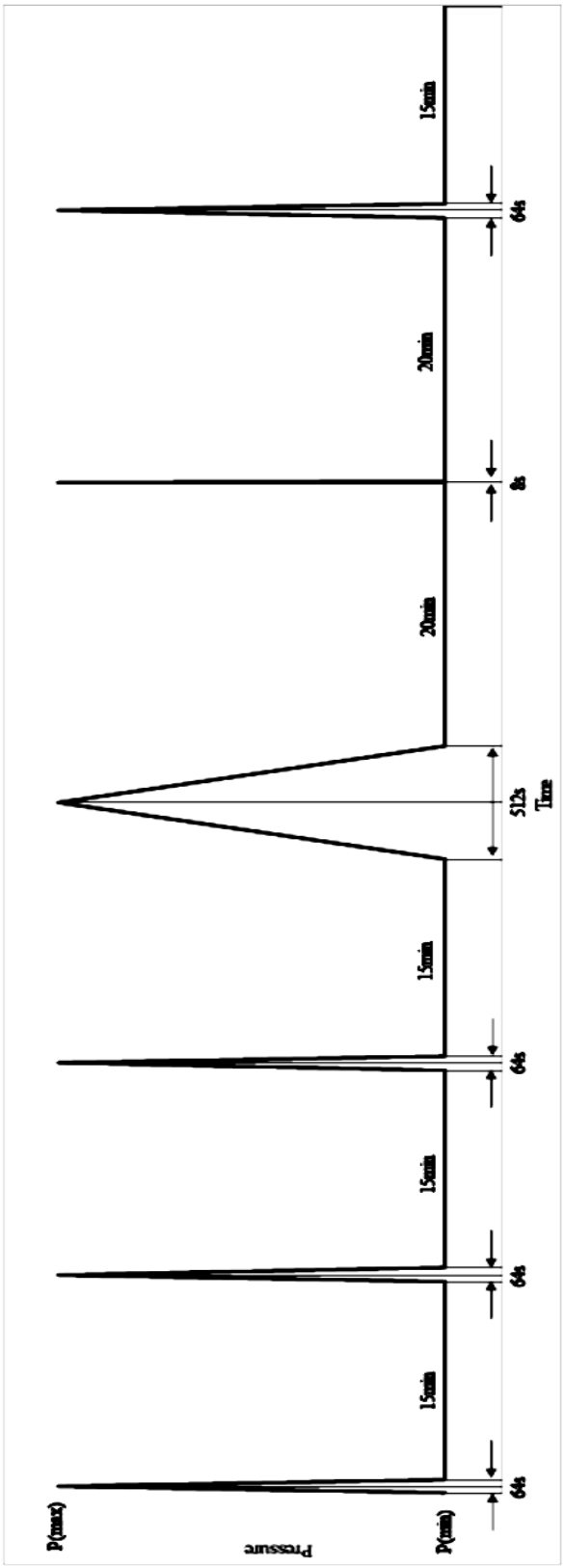

P(max)
P(min)
Pressure
Time
15min
64s
20min
8s
20min
512s
15min
64s
15min
64s
15min
64s

Figure 9

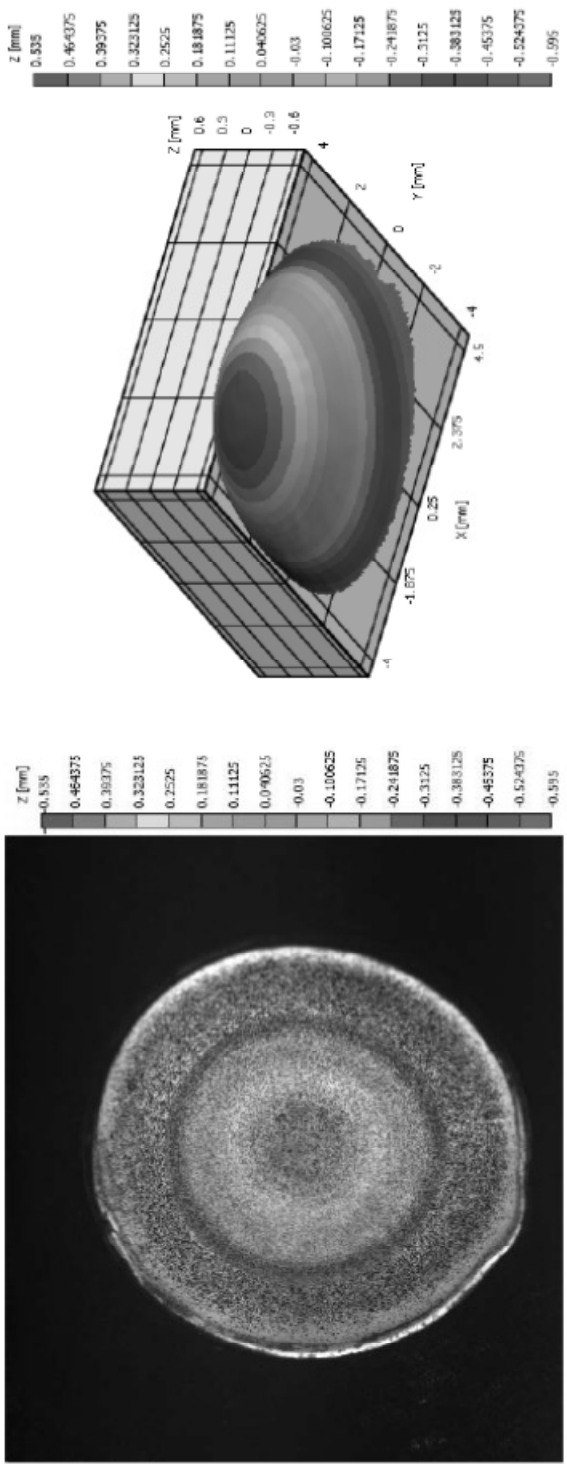


Figure 10A

Figure 10B

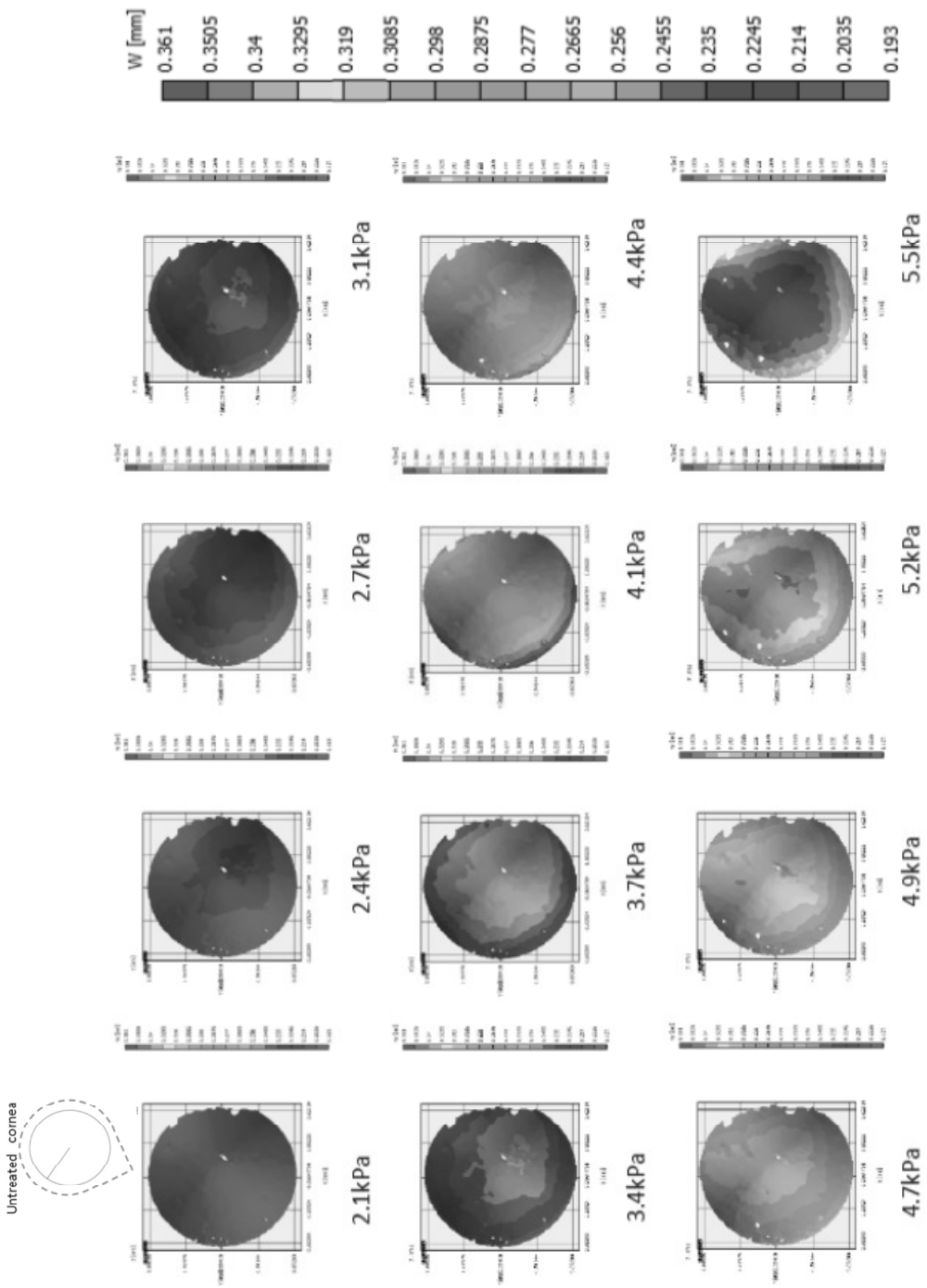

W [mm]
0.361
0.3505
0.34
0.3295
0.319
0.3085
0.298
0.2875
0.277
0.2665
0.256
0.2455
0.235
0.2245
0.214
0.2035
0.193
Untreated_cornea
2.1kPa
2.4kPa
2.7kPa
3.1kPa
3.4kPa
3.7kPa
4.1kPa
4.4kPa
4.7kPa
4.9kPa
5.2kPa
5.5kPa

Figure 11

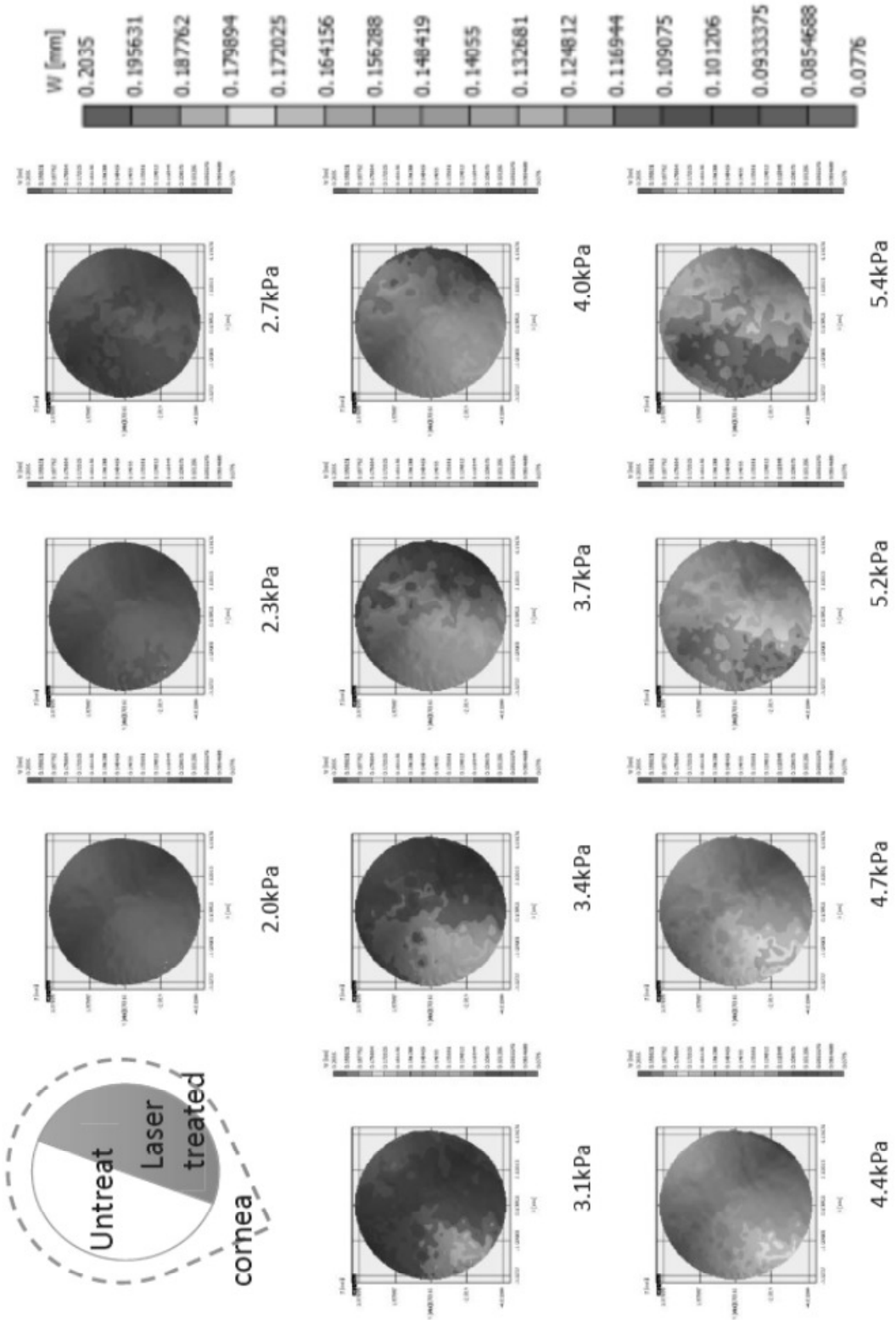

W [mm]
0.2035
0.195631
0.187762
0.179894
0.172025
0.164156
0.156288
0.148419
0.14055
0.132681
0.124812
0.116944
0.109075
0.101206
0.0933375
0.0854688
0.0776
Untreat
Laser treated
cornea
2.0kPa
2.3kPa
2.7kPa
3.1kPa
3.4kPa
3.7kPa
4.0kPa
4.4kPa
4.7kPa
5.2kPa
5.4kPa

Figure 12

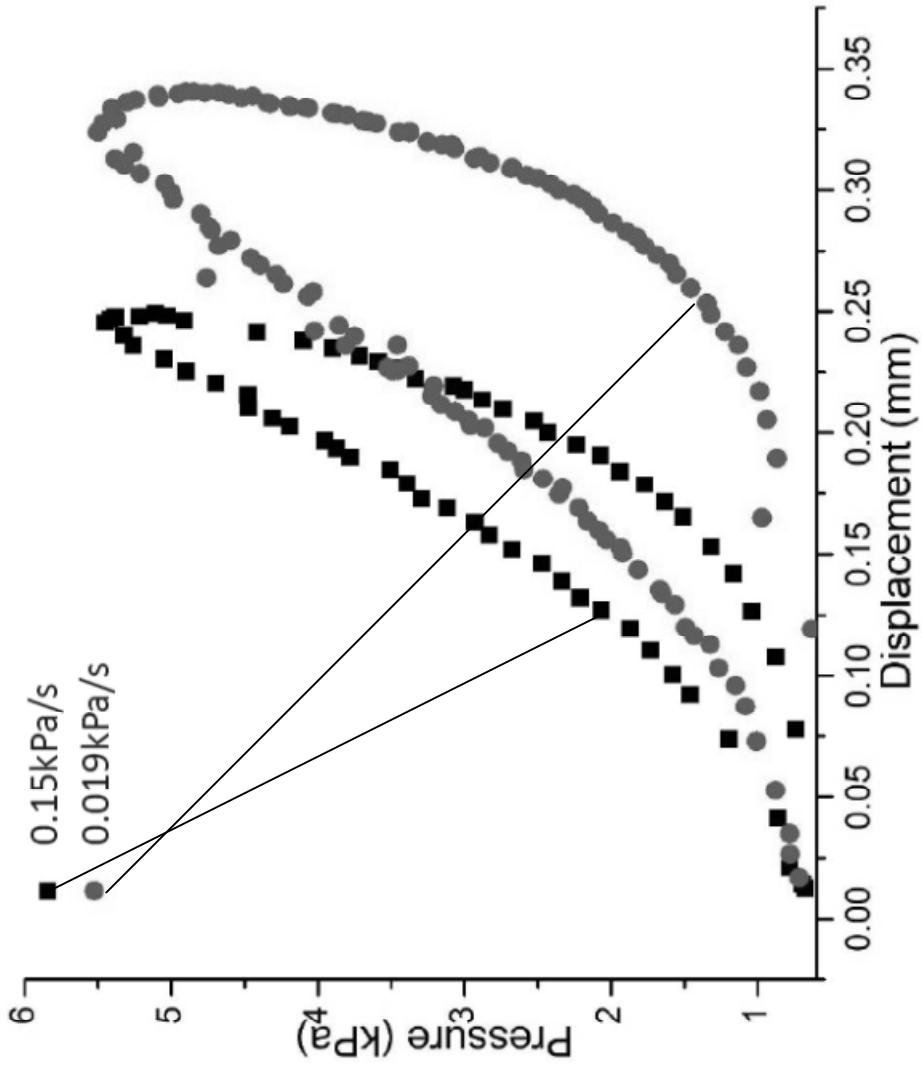

0.15kPa/s
0.019kPa/s
Pressure (kPa)
Displacement (mm)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
1
2
3
4
5
6

Figure 13

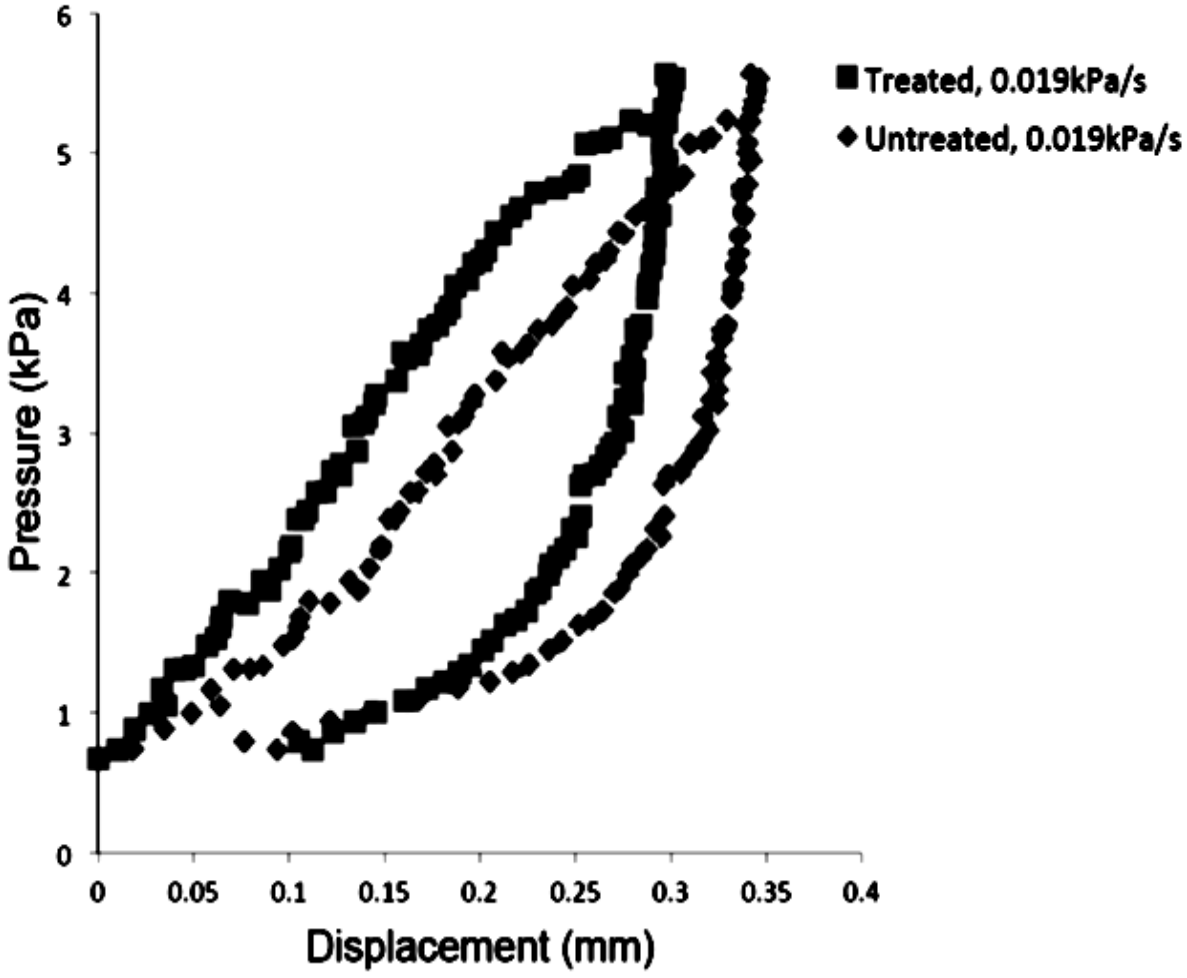

Pressure (kPa)
Displacement (mm)
Treated, 0.019kPa/s
Untreated, 0.019kPa/s
0
1
2
3
4
5
6
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4

Figure 14

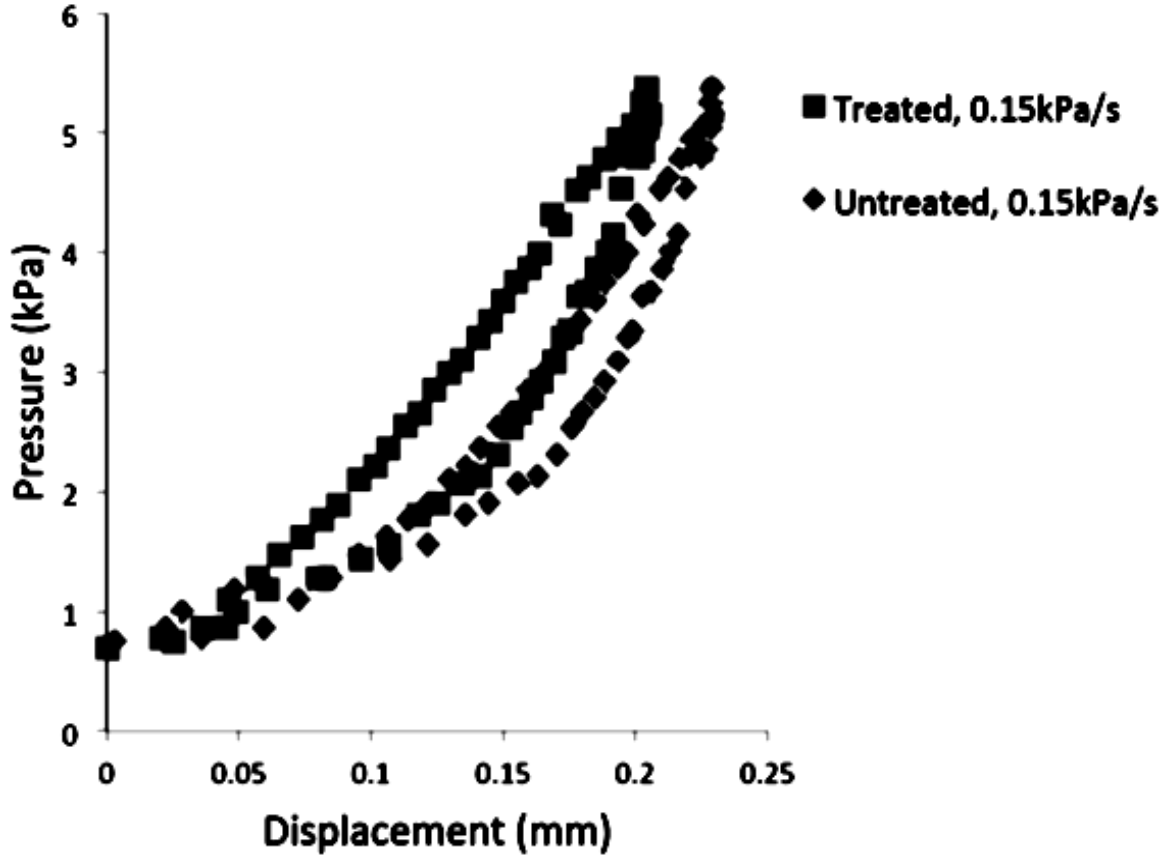

Pressure (kPa)
Displacement (mm)
0
1
2
3
4
5
6
0
0.05
0.1
0.15
0.2
0.25
Treated, 0.15kPa/s
Untreated, 0.15kPa/s

Figure 15

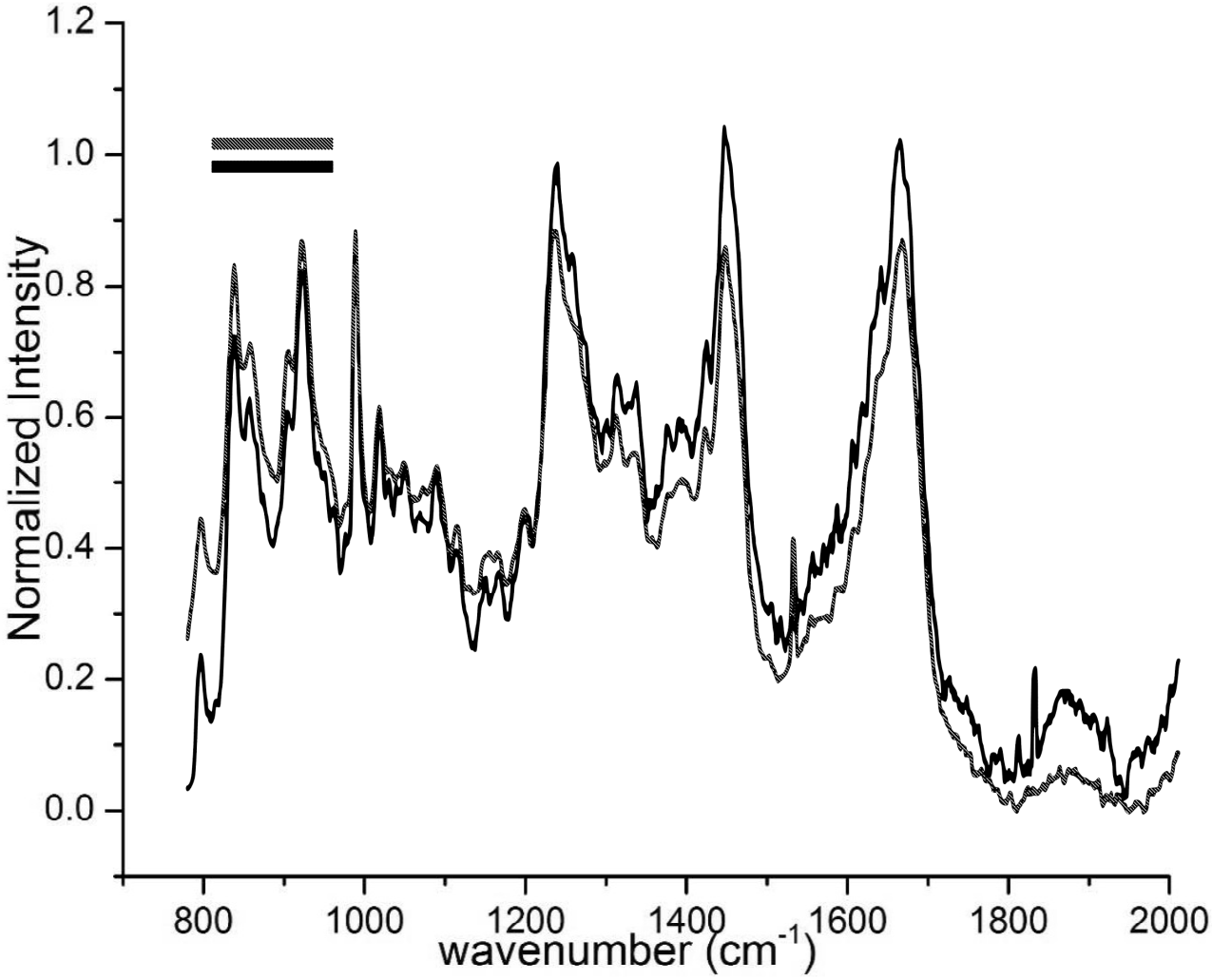

1.2
1.0
0.8
0.6
0.4
0.2
0.0
Normalized Intensity
800
1000
1200
1400
1600
1800
2000
wavenumber (cm-1)

Figure 16

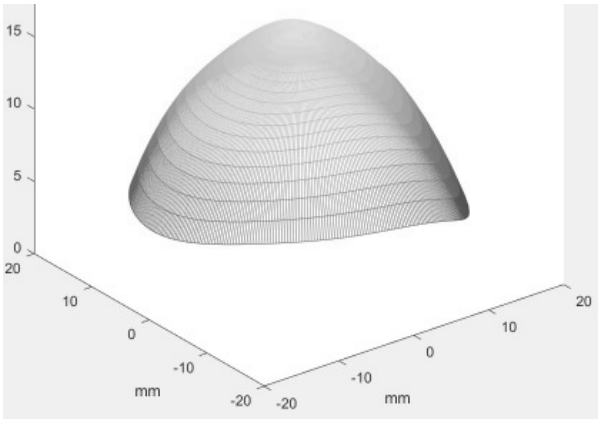


Figure 17A

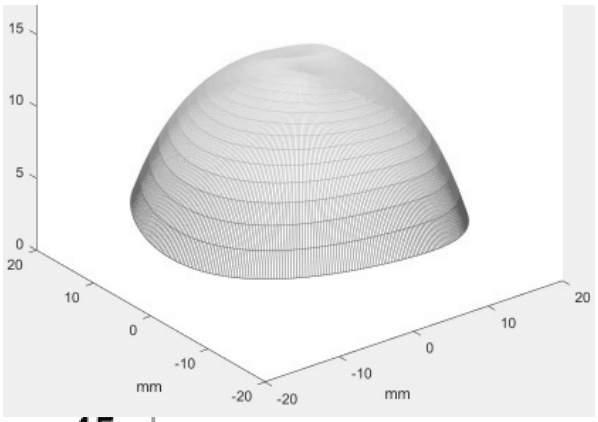


Figure 17B

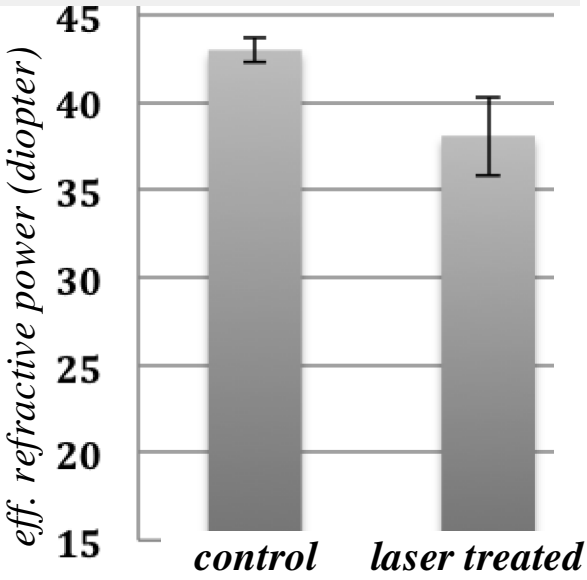


Figure 17C

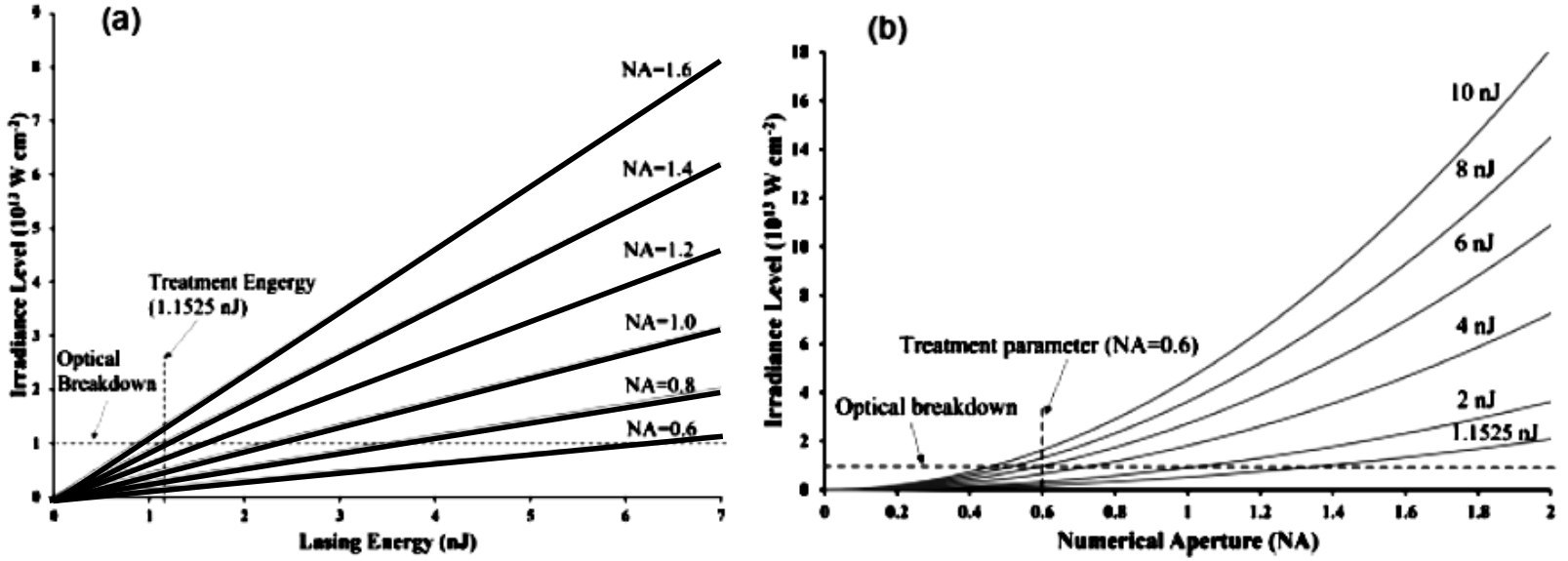


Figure 18 (a) The average lasing energy vs treatment lasing irradiance level curves. The optical breakdown is approximately 1.0 × 10^{13} W cm^{-2} and the corresponding average energy intensity for the applied laser would be 0.319 W while the treatment applied an average energy 1.1525 nJ and the corresponding irradiance level is round 0.19 × 10^{13} W cm^{-2}; (b) The objective numerical aperture vs treatment lasing irradiance level curve. The optical breakdown is approximately 1.0 × 10^{13} W cm^{-2} and numerical aperture required to achieve optical breakdown at treatment irradiance is 1.384.

Figure 18A **Figure 18B**

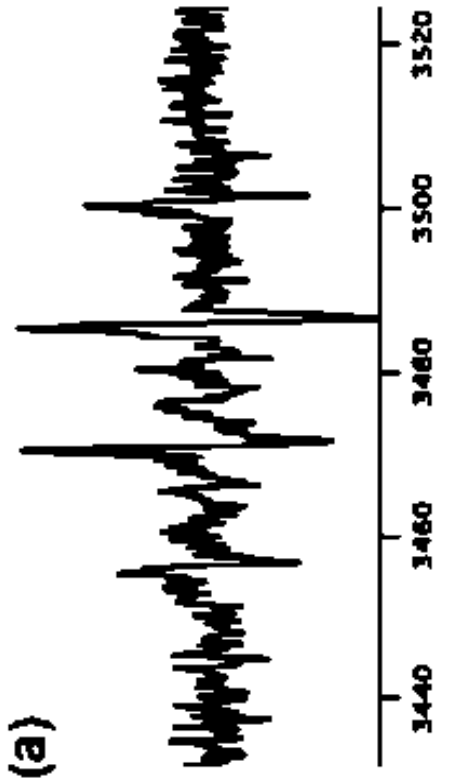


Figure 19A

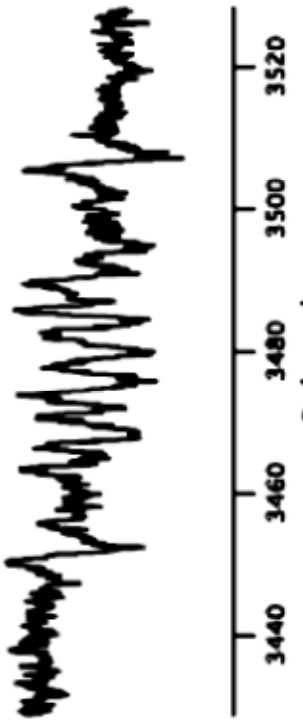


Figure 19B

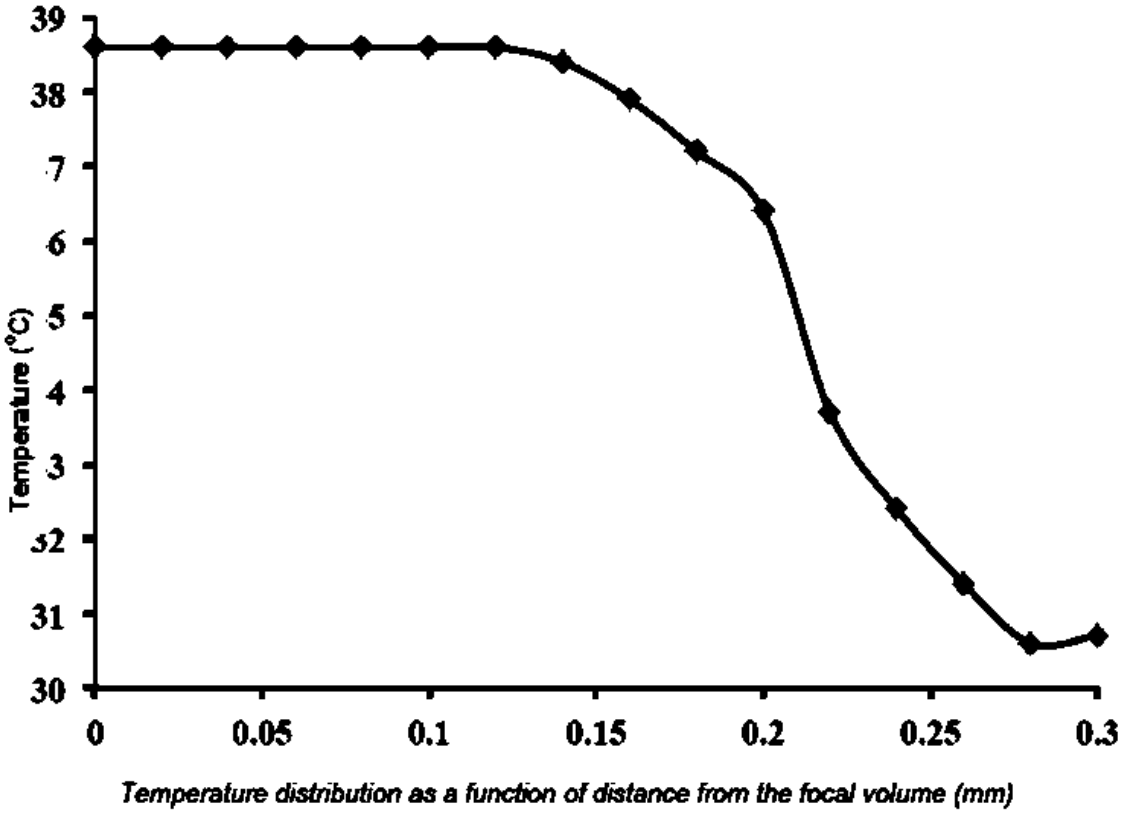

39
38
7
6
5
4
3
52
31
30
Temperature (°C)
0
0.05
0.1
0.15
0.2
0.25
0.3
Temperature distribution as a function of distance from the focal volume (mm)

Figure 20

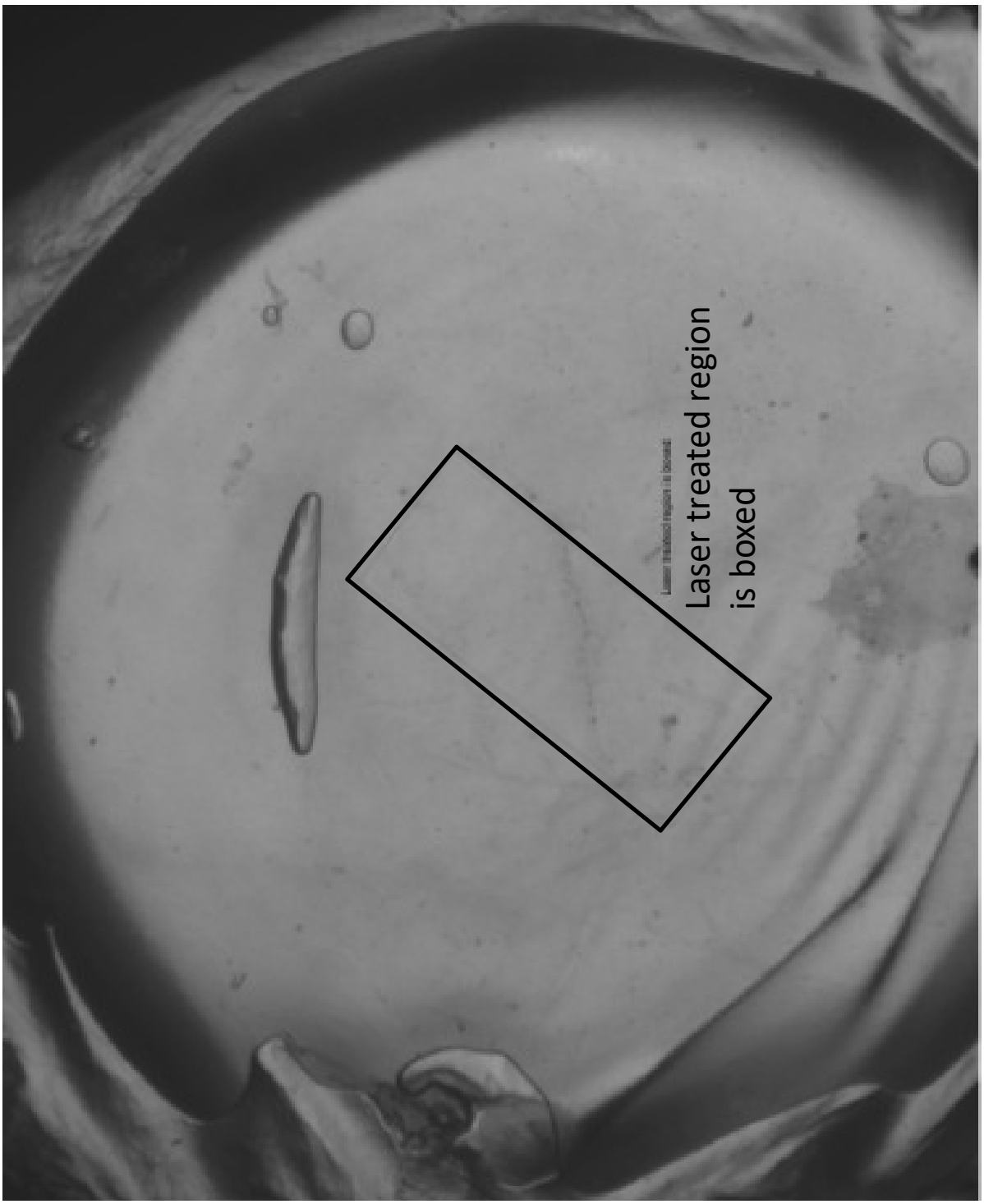


Figure 21

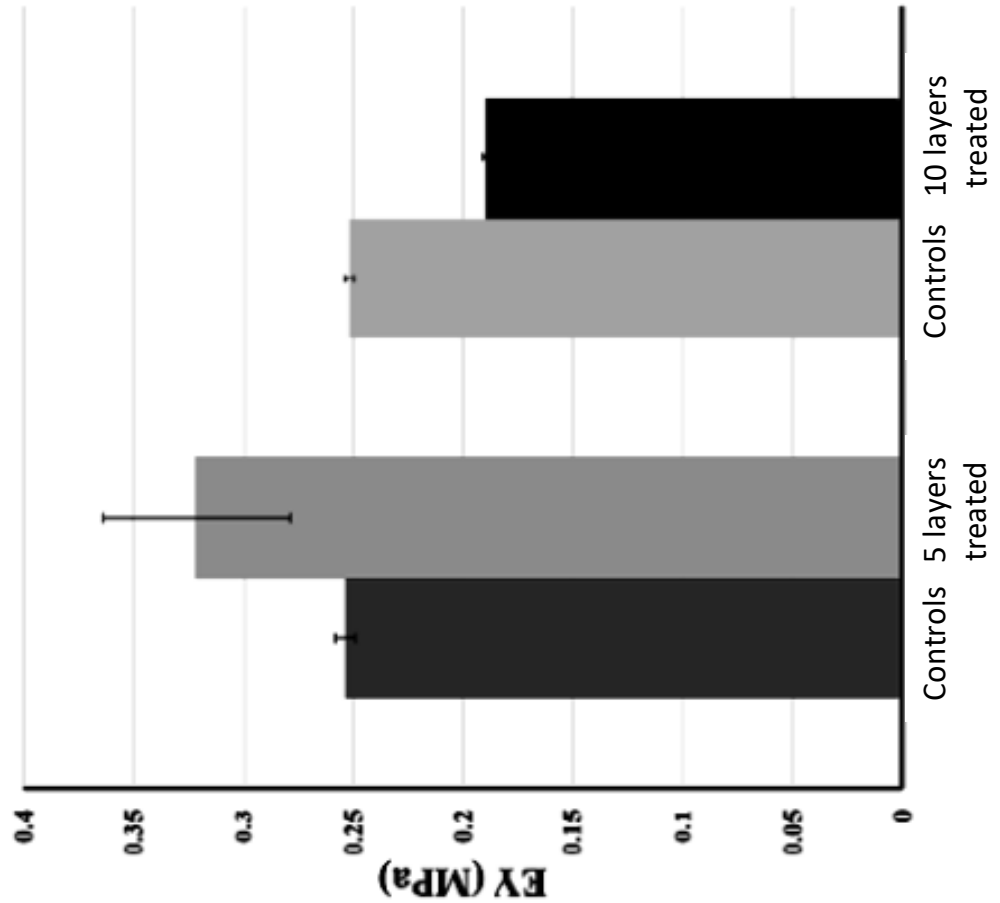


Figure 22B

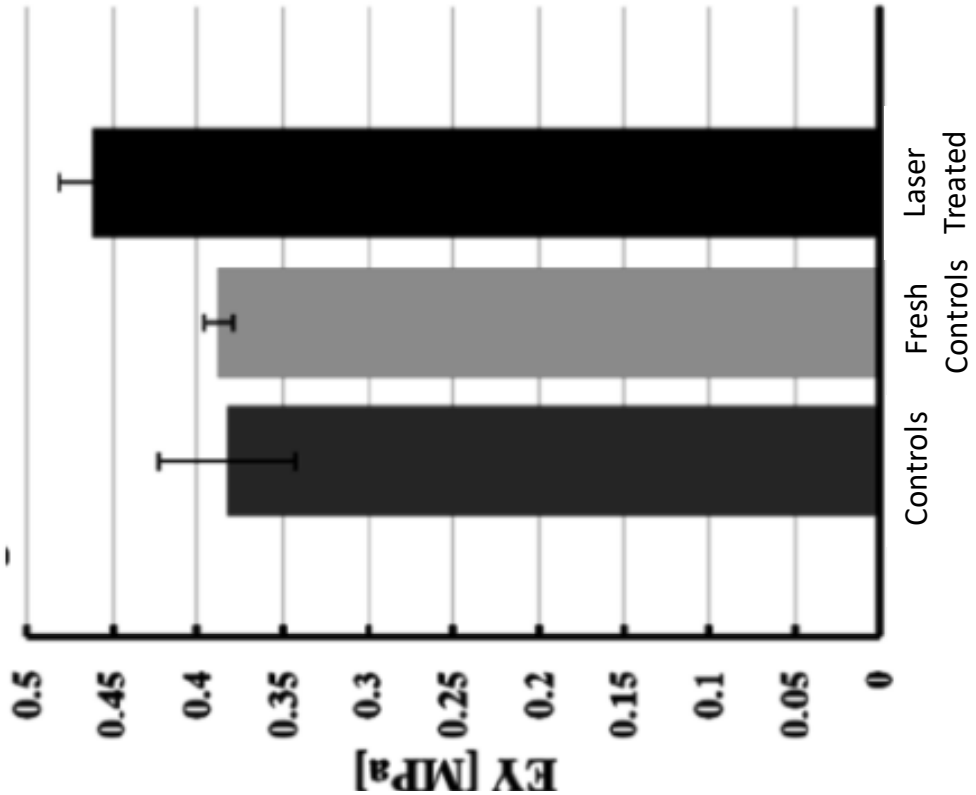


Figure 22A