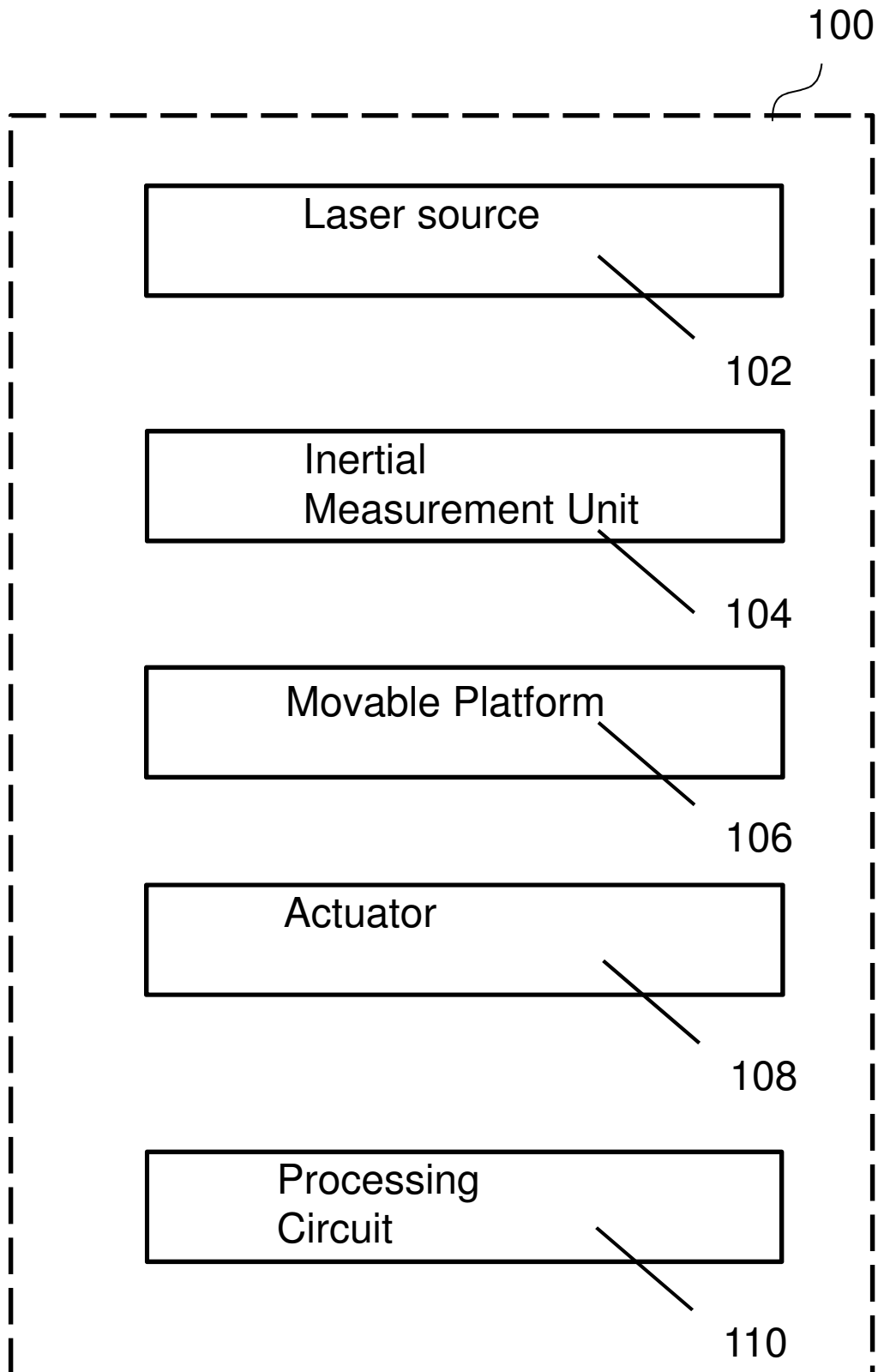
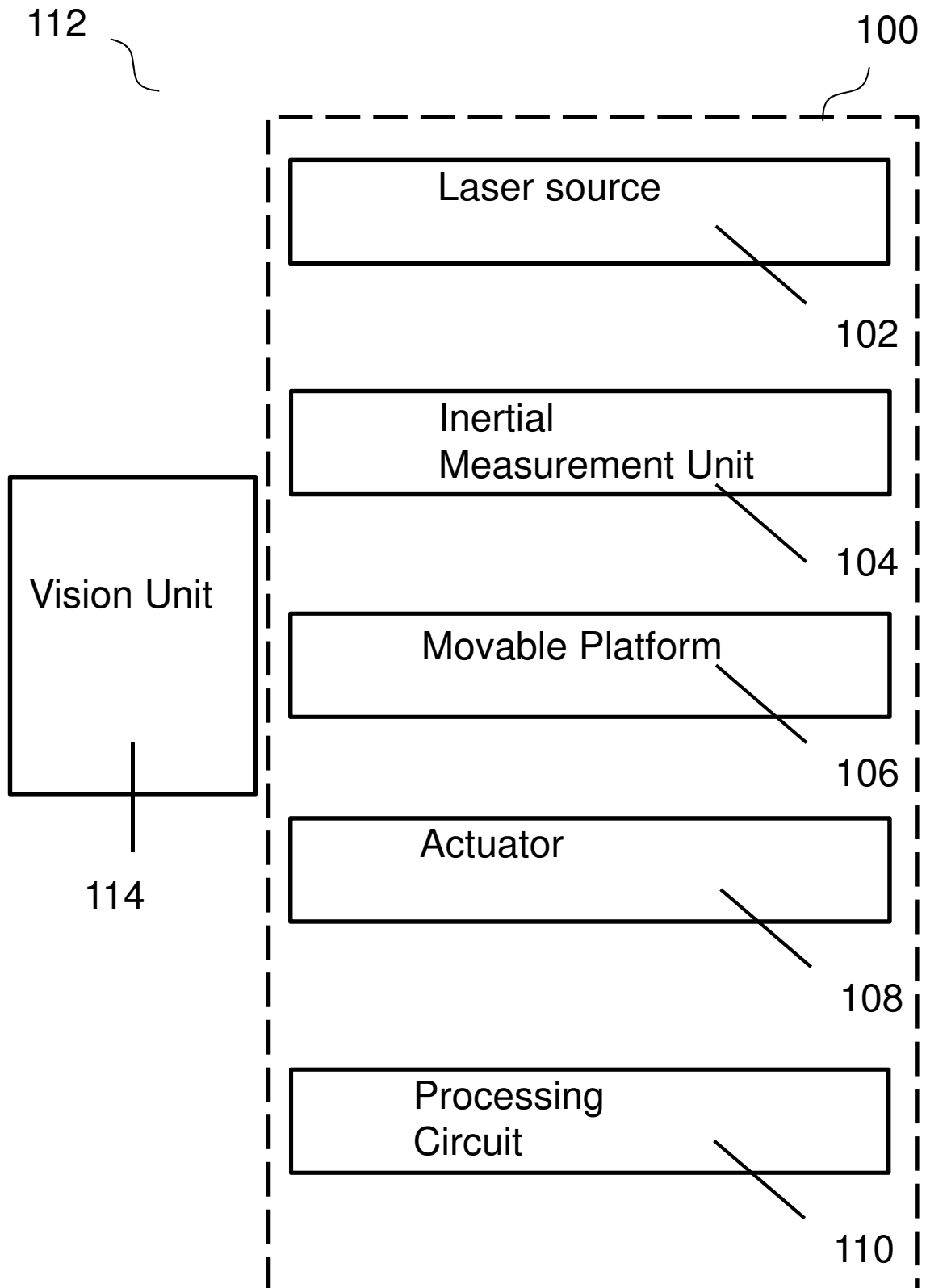


1/30
FIG. 1A



2/30
FIG. 1B



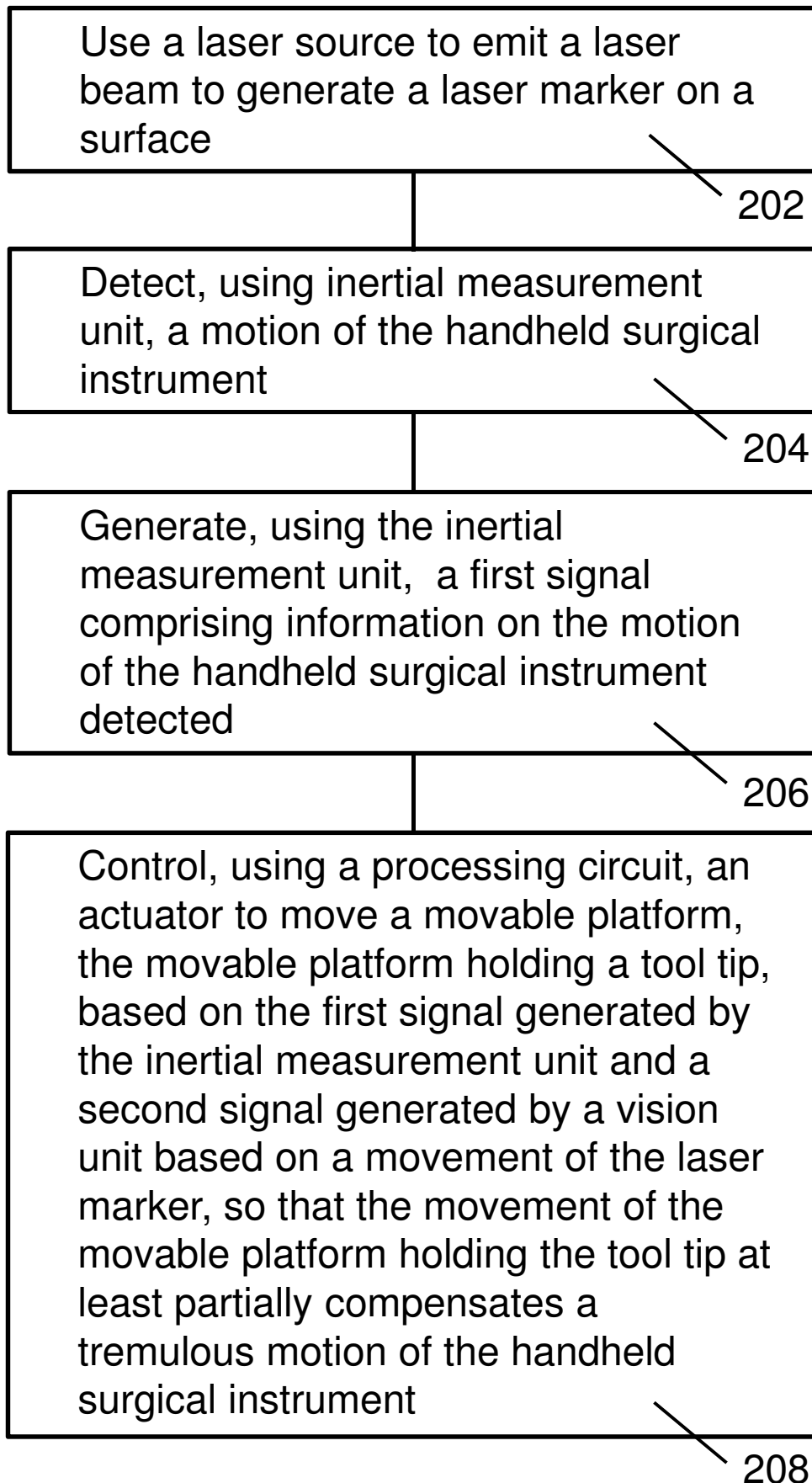
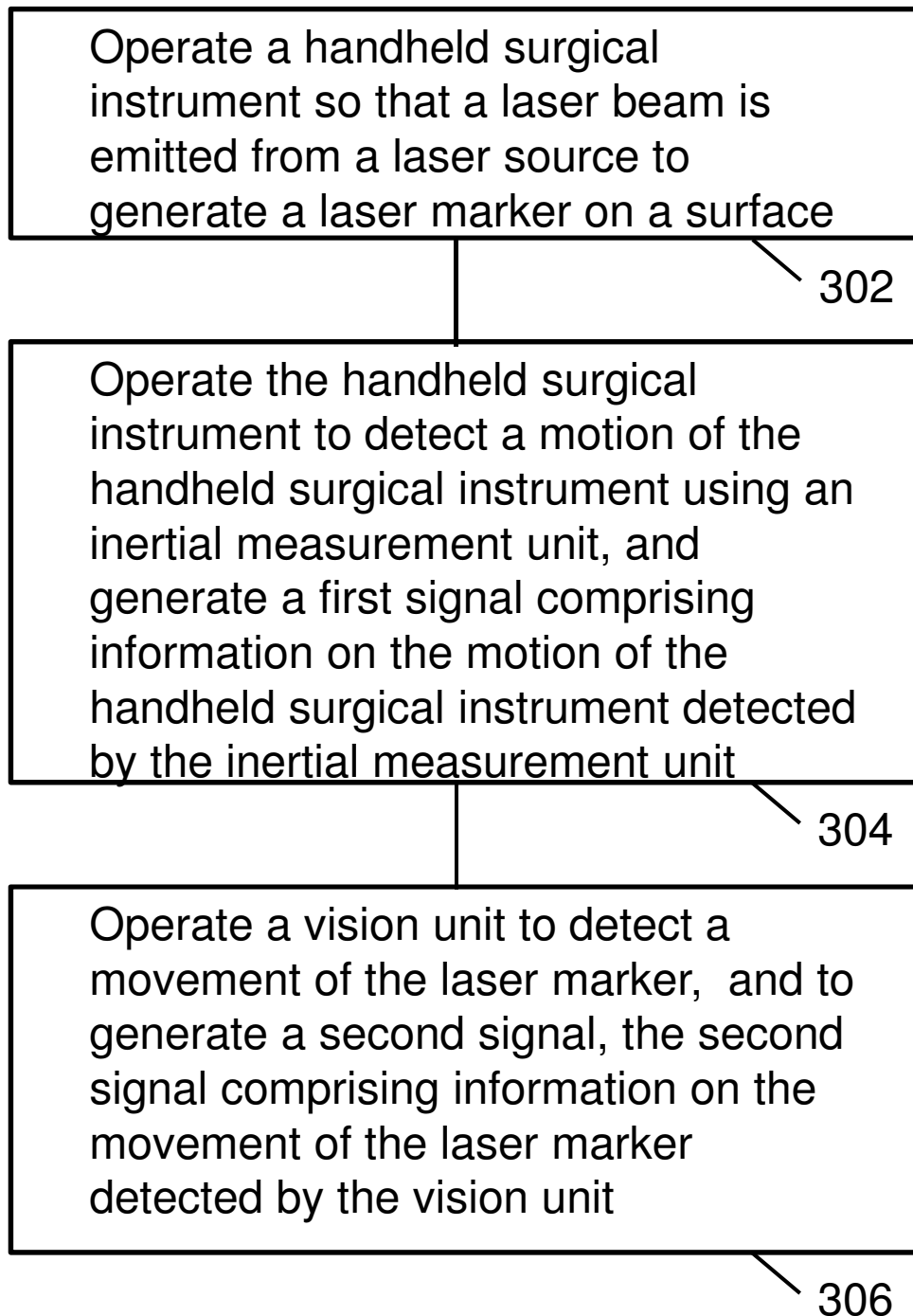
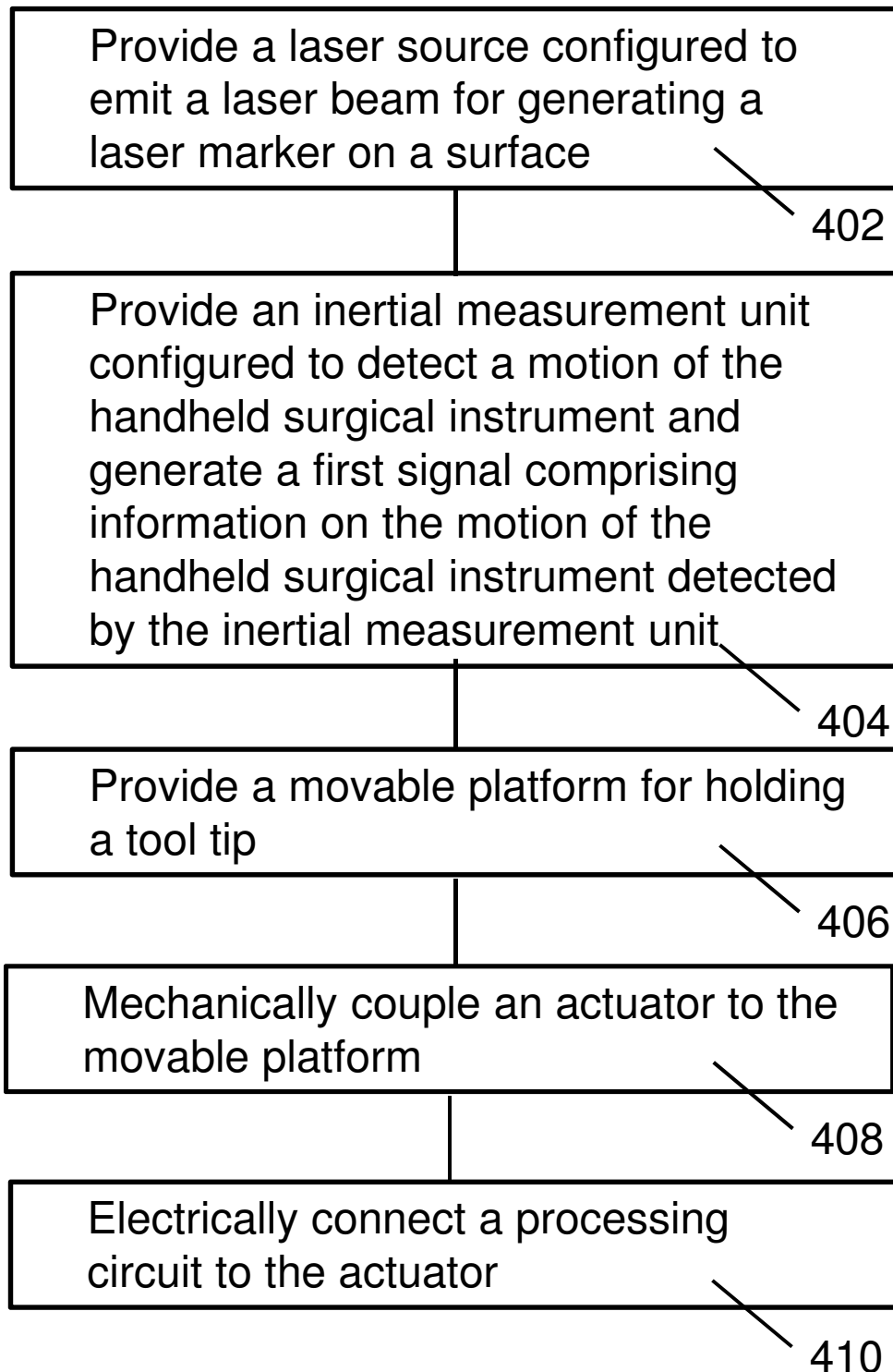
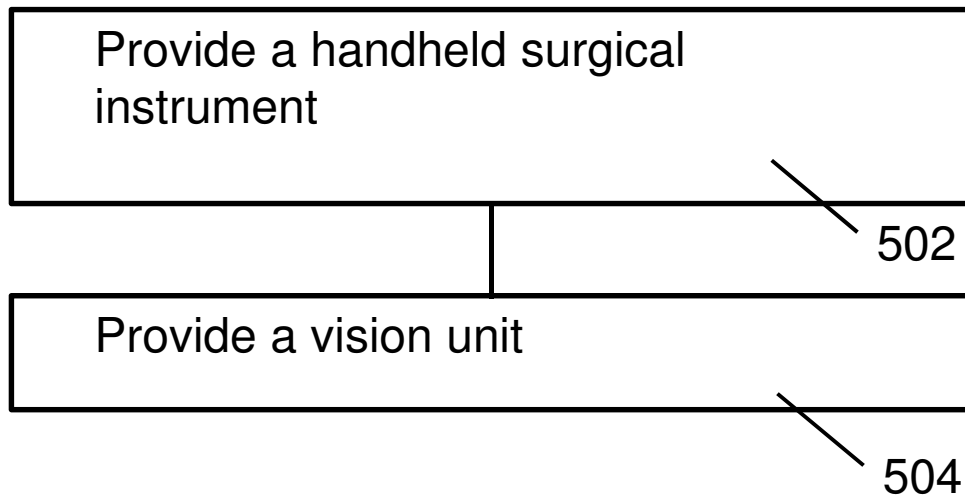


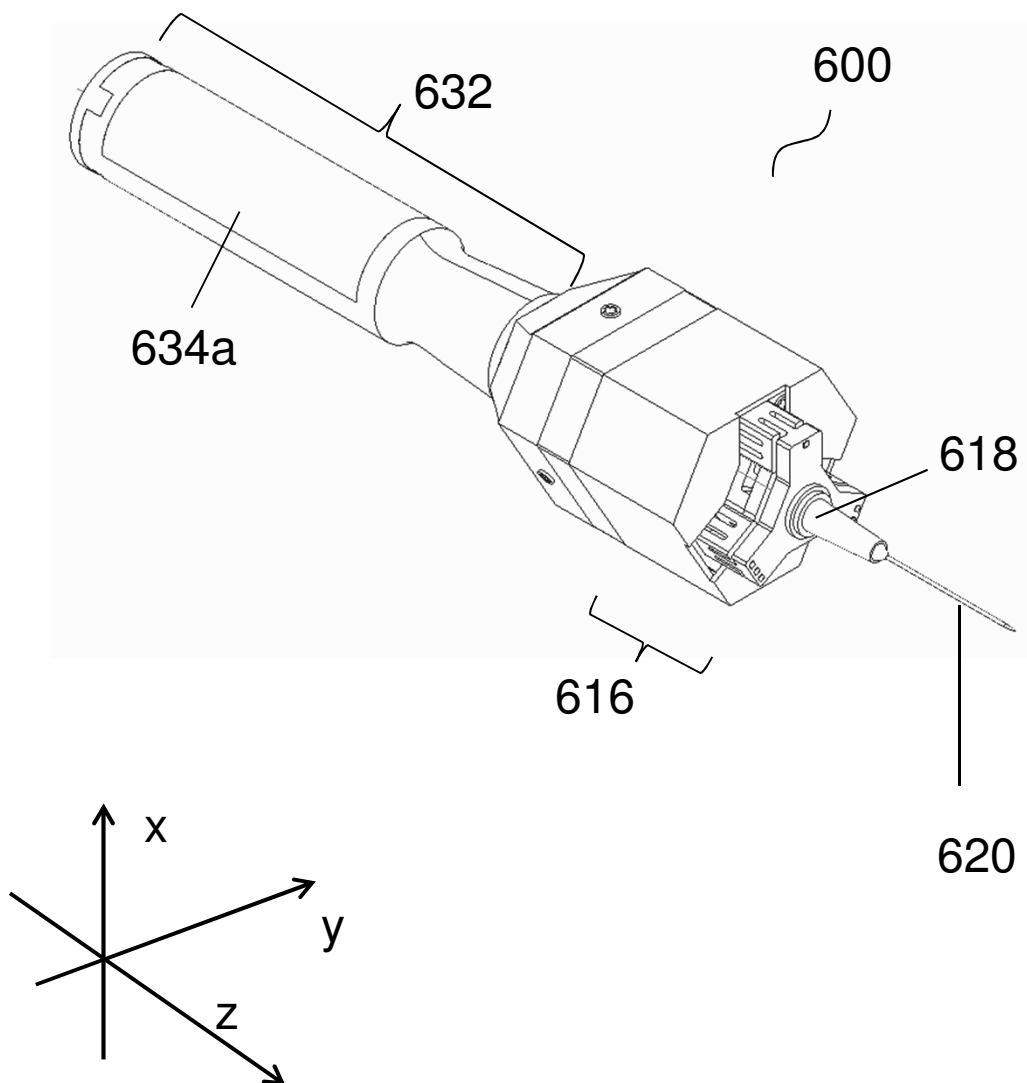
FIG. 3



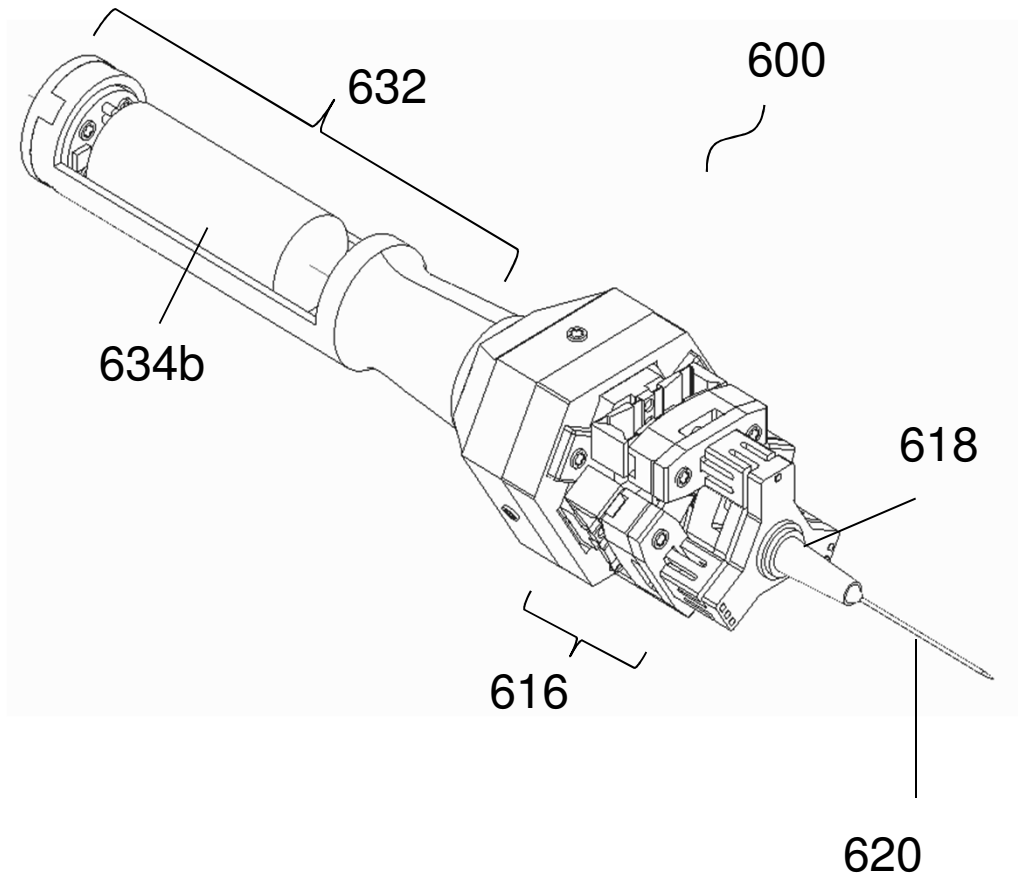
6/30
FIG. 5



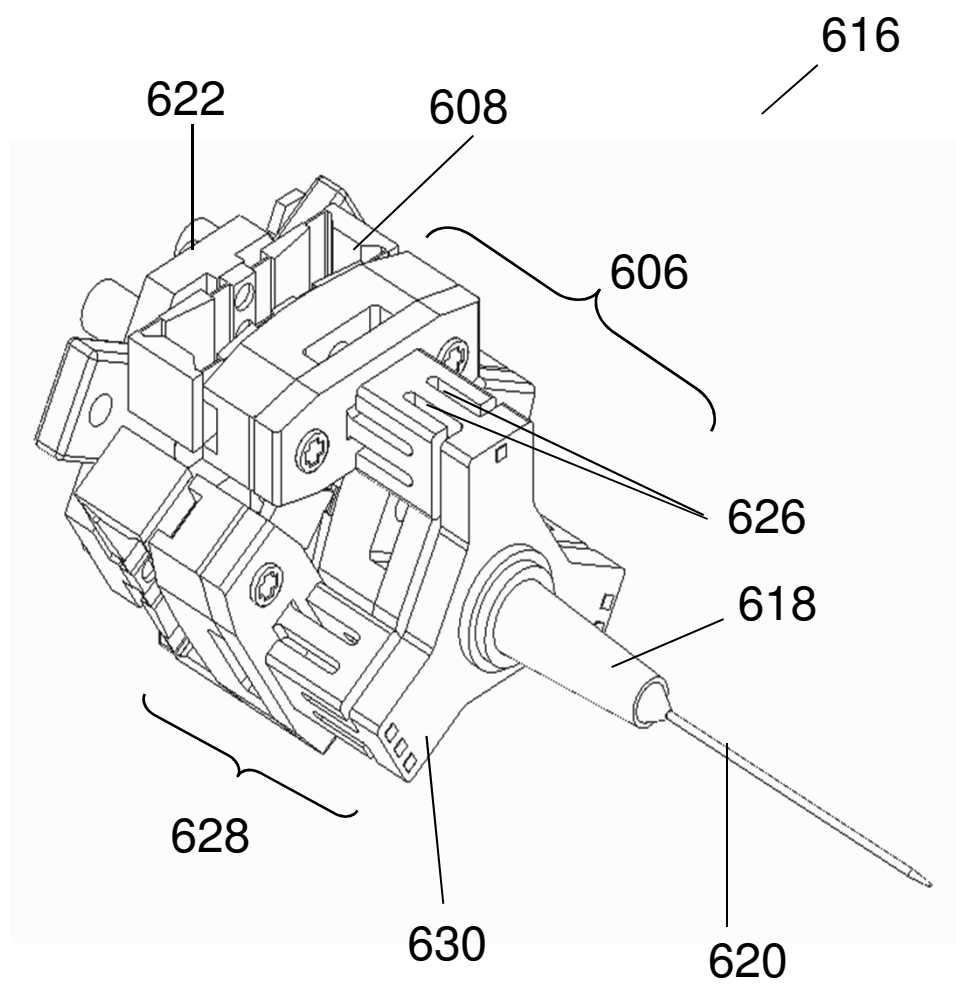
7/30
FIG. 6A



8/30
FIG. 6B



9/30
FIG. 6C



10/30
FIG. 6D

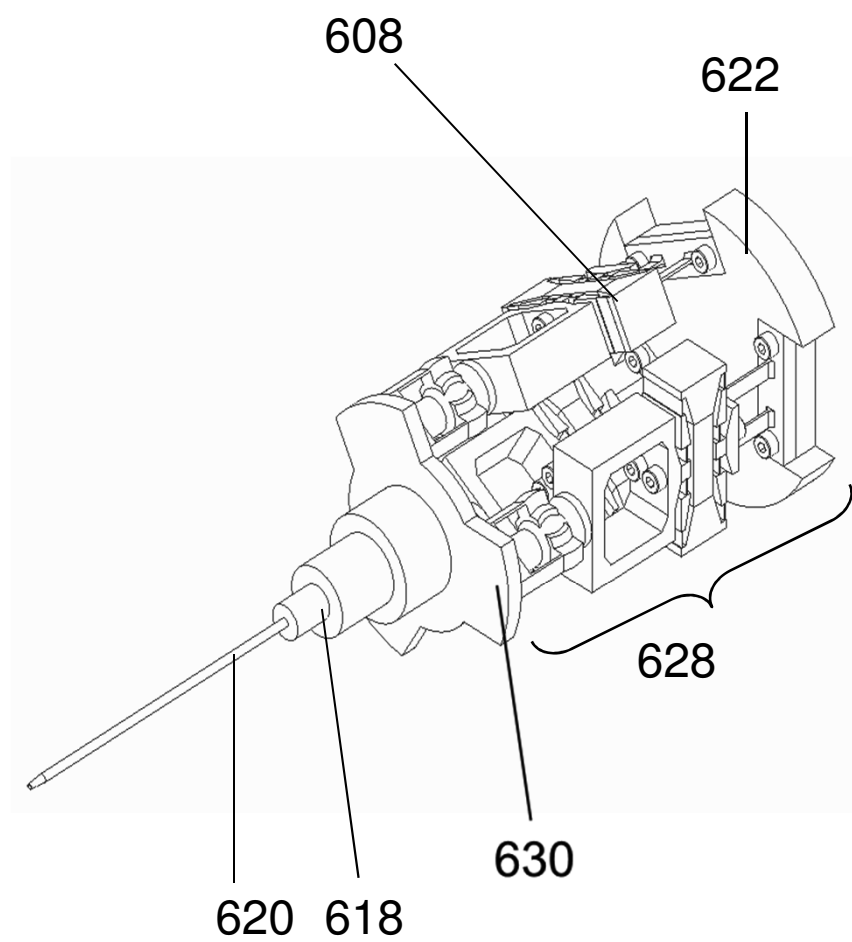
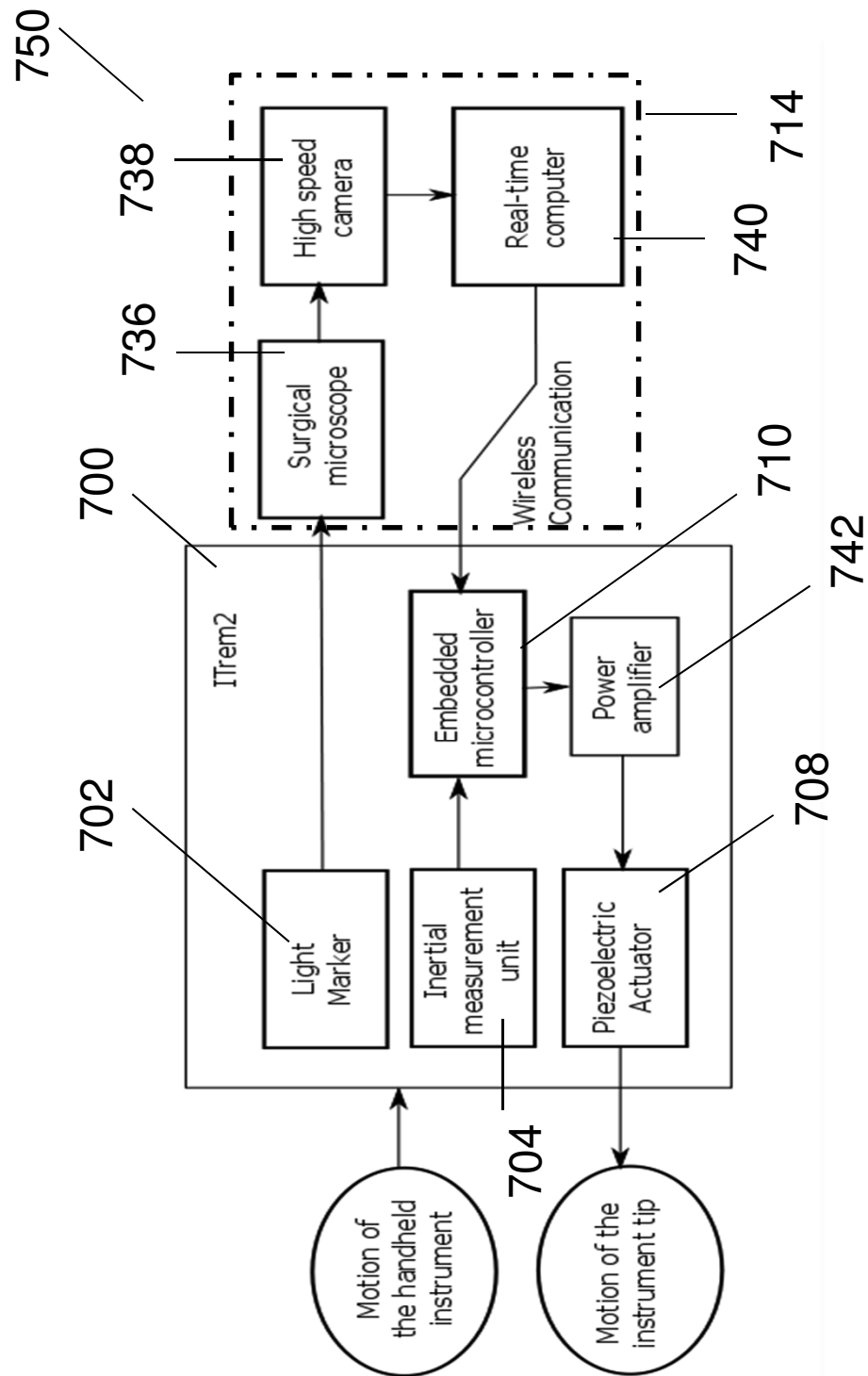
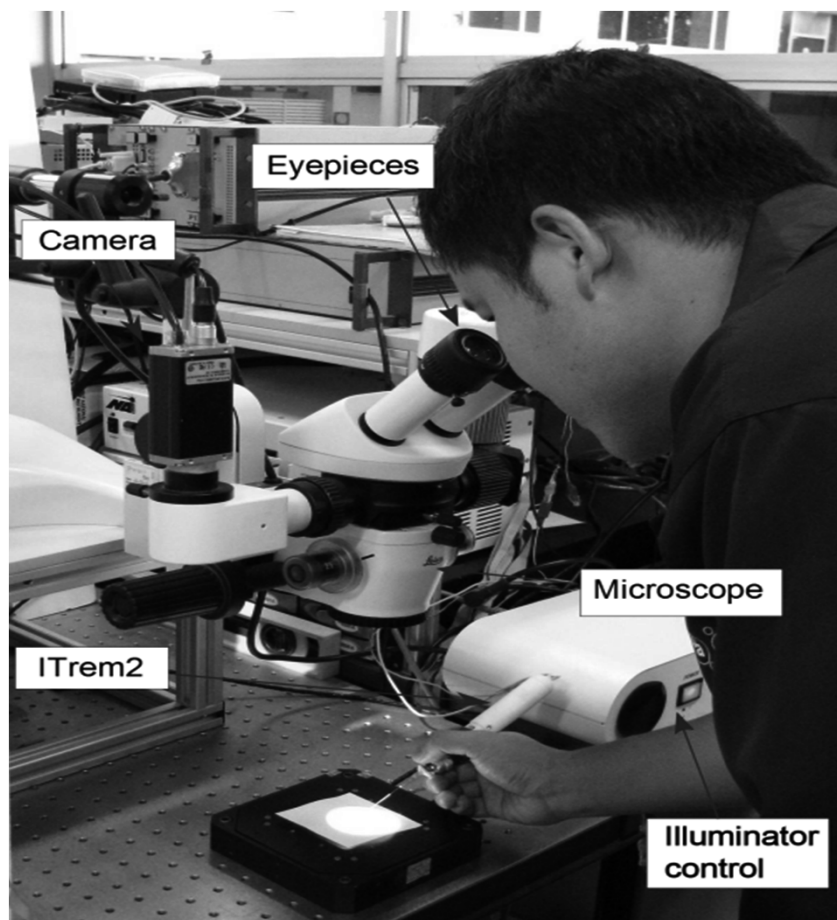


FIG. 7A



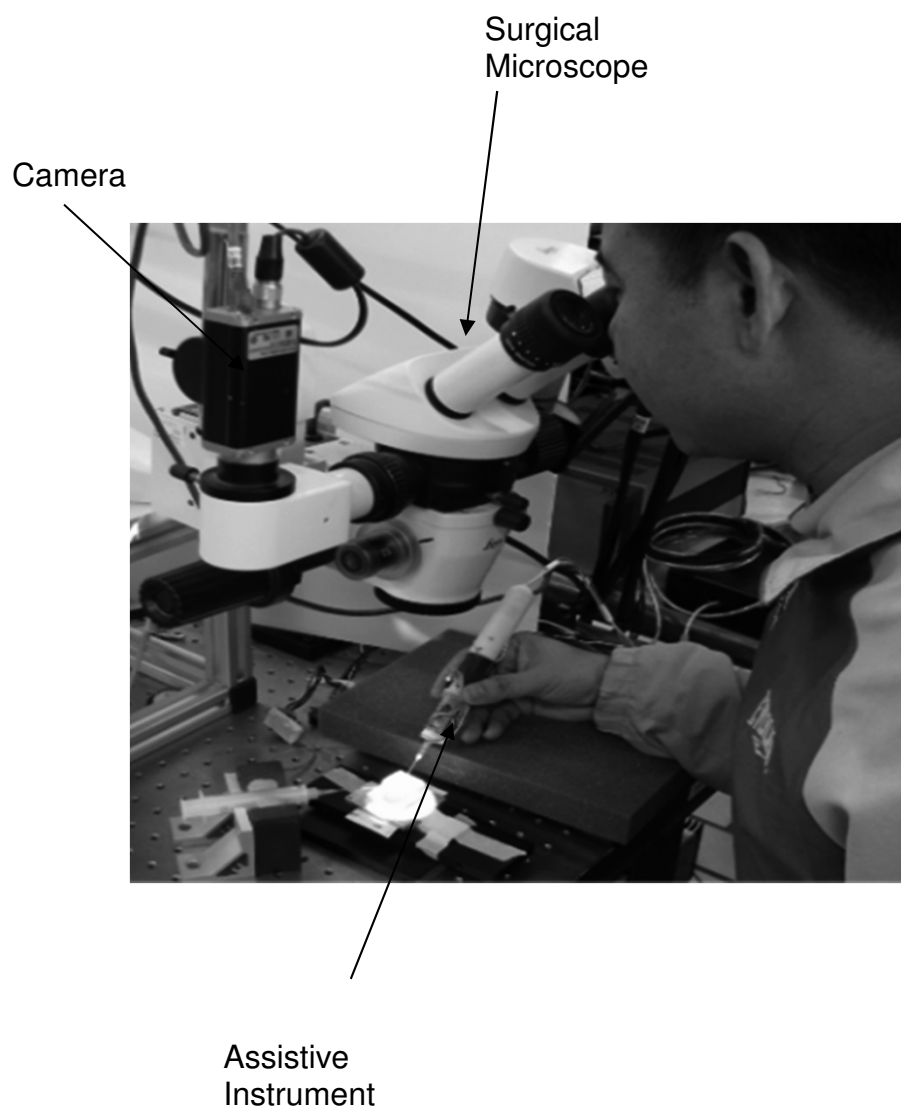
12/30
FIG. 7B

770

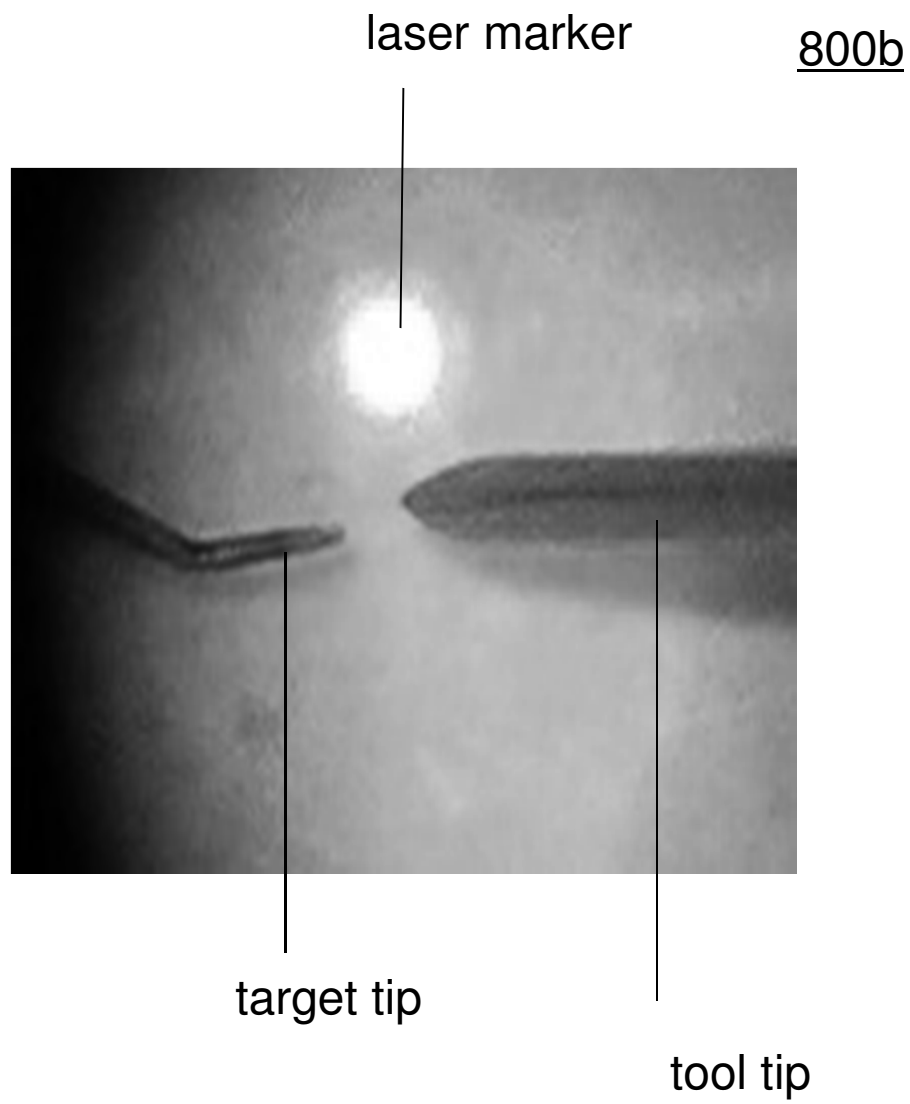


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FIG. 8A

800a

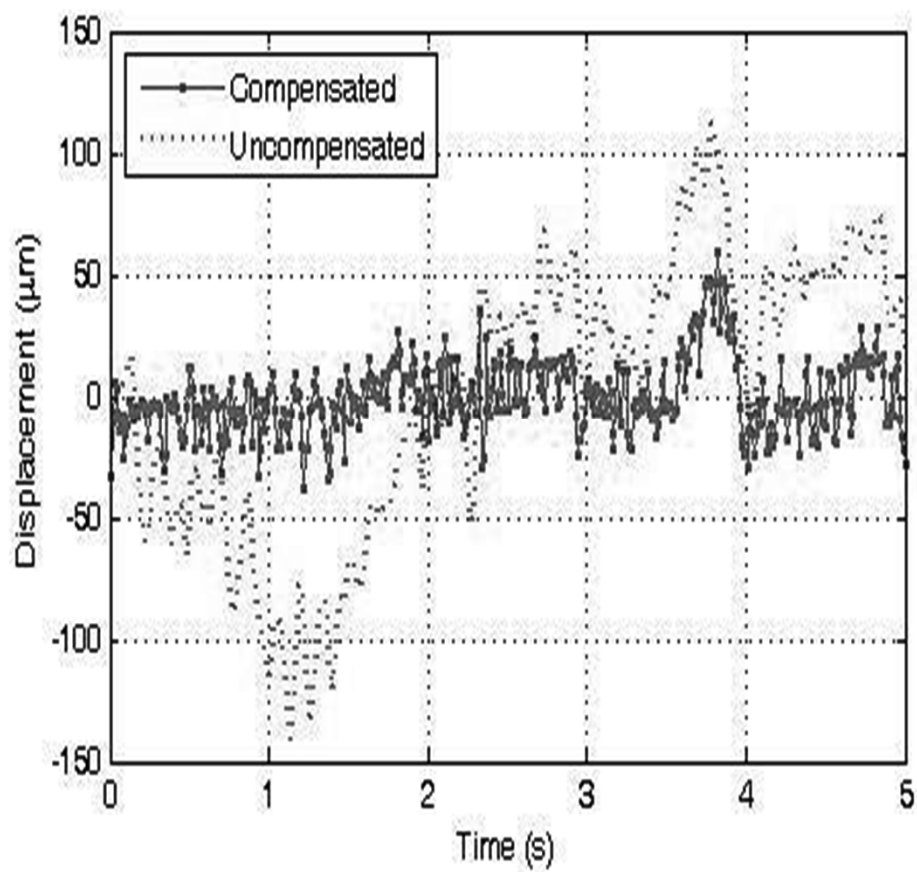


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FIG. 8B



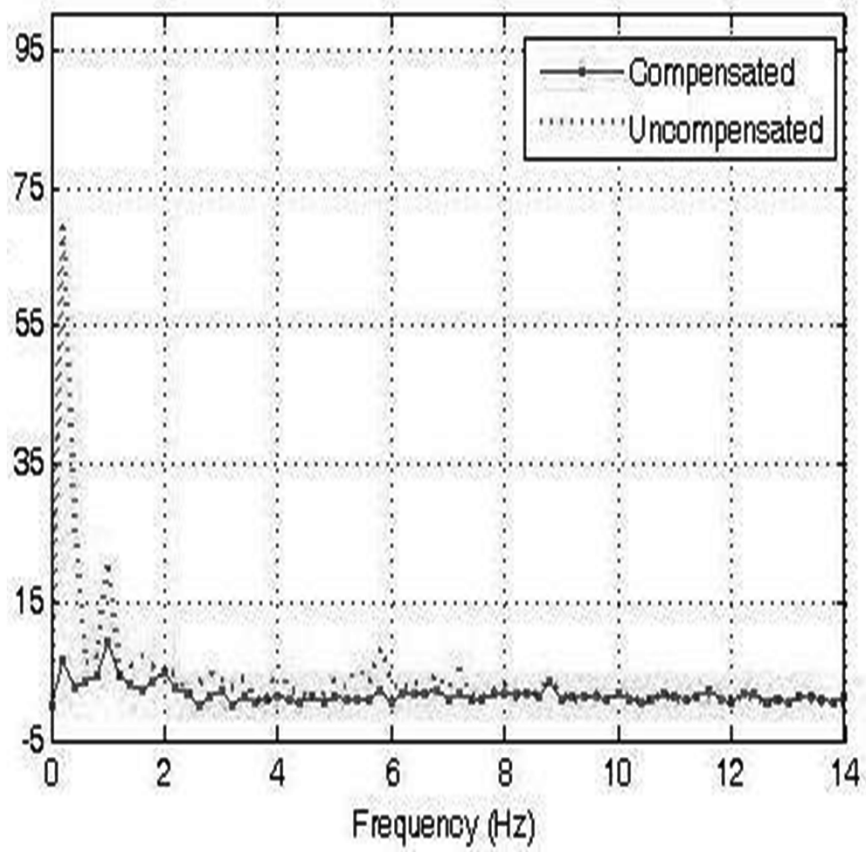
15/30
FIG. 9A

900a



16/30
FIG. 9B

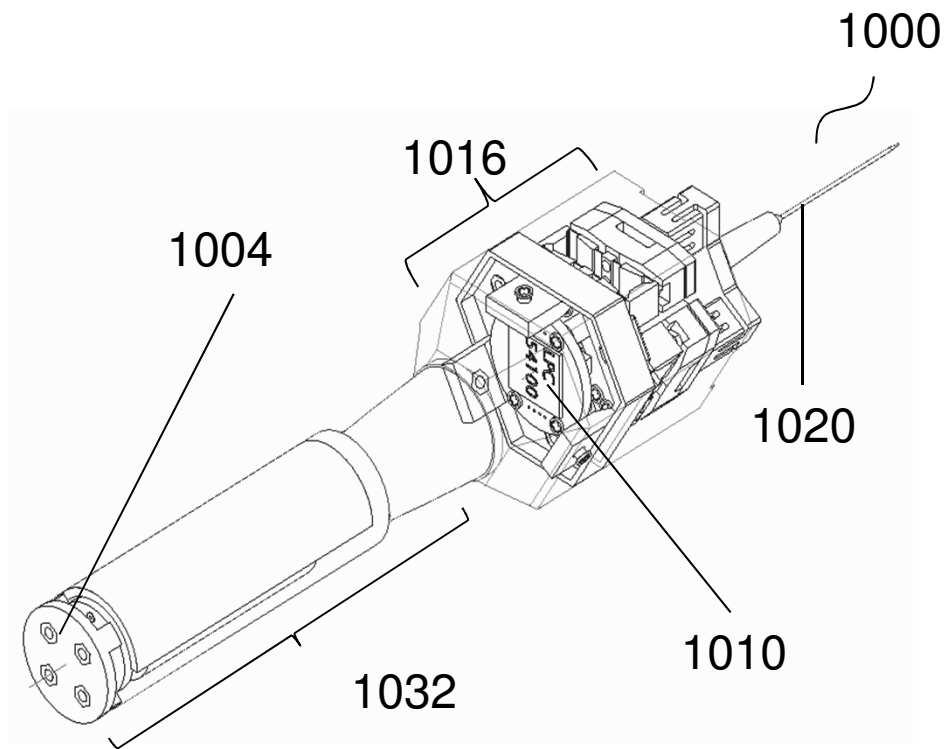
900b



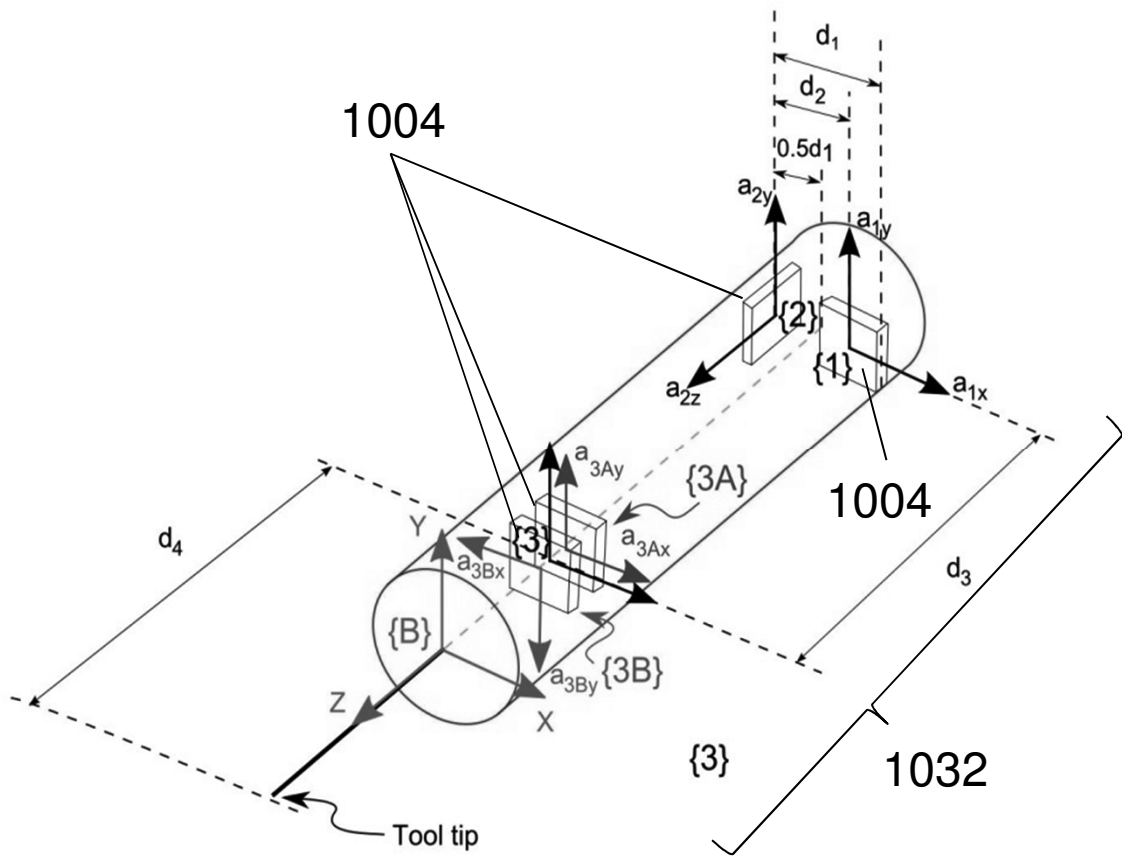
900c

Tip Displacement	Max Peak-Peak (μm)	Attenuation (%)	Root Mean Square (μm)	Attenuation (%)
Uncompensated	253	61.3	60	73.3
Compensated	98		16	

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FIG. 10A



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FIG. 10B



Design	Micron II	ITrem2
Standard deviation of angular acceleration with respect to X axis (rad/s ²)	0.102	0.086
Standard deviation of angular acceleration with respect to Y axis (rad/s ²)	0.704	0.103
Standard deviation of angular acceleration with respect to Z axis (rad/s ²)	0.704	0.951
Standard deviation of linear acceleration along X axis (mm/s ²)	57.10	13.69
Standard deviation of linear acceleration along Y axis (mm/s ²)	17.21	12.92
Standard deviation of linear acceleration along Z axis (mm/s ²)	7.07	9.90
Resultant standard deviation of tool tip linear acceleration	59.82	21.05

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FIG. 11A

1100a

← A_{n-31}		A_{n-1}	A_n	← Acceleration measurement
← t_{n-31}		t_{n-1}	t_n	← Time stamp

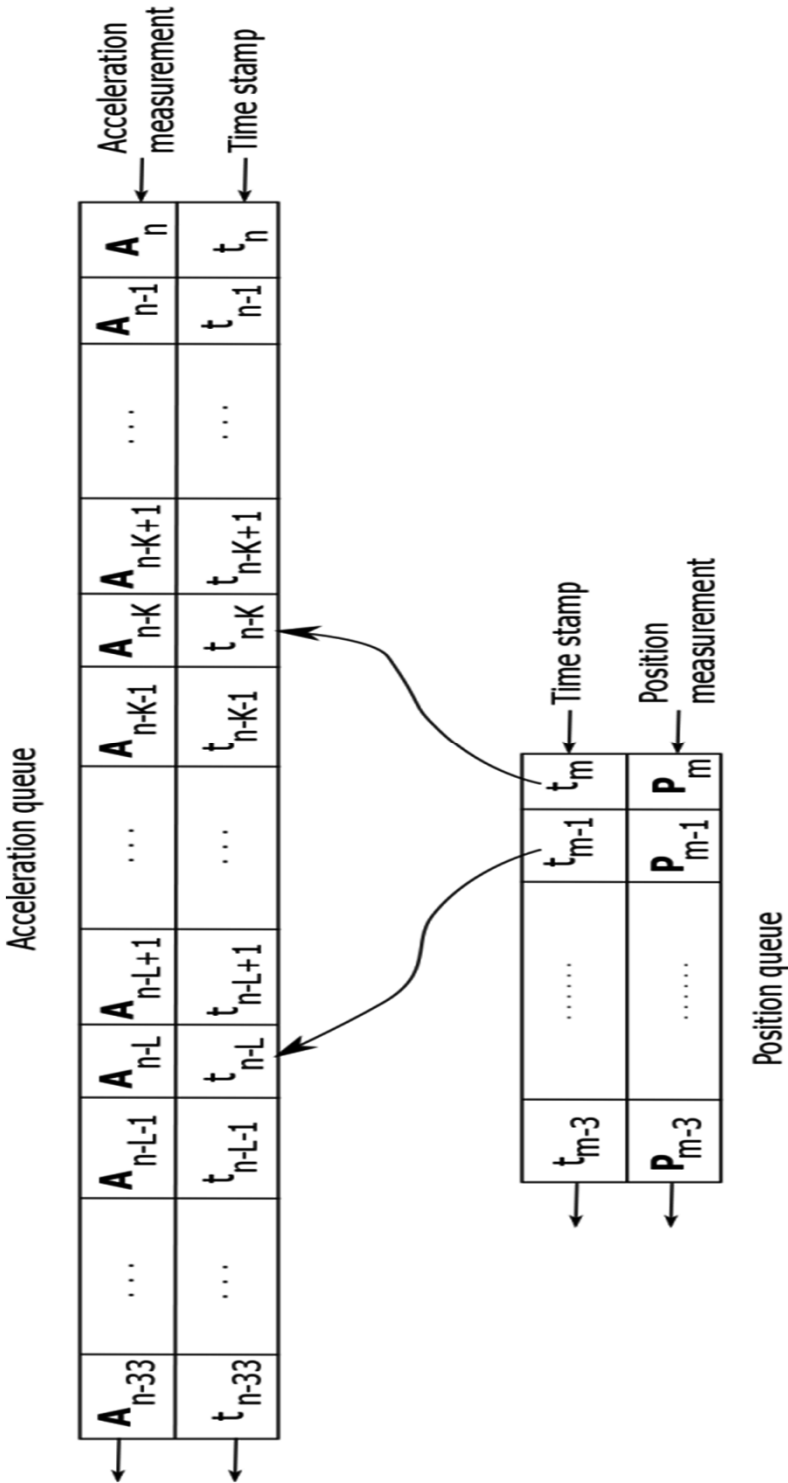
FIG. 11B

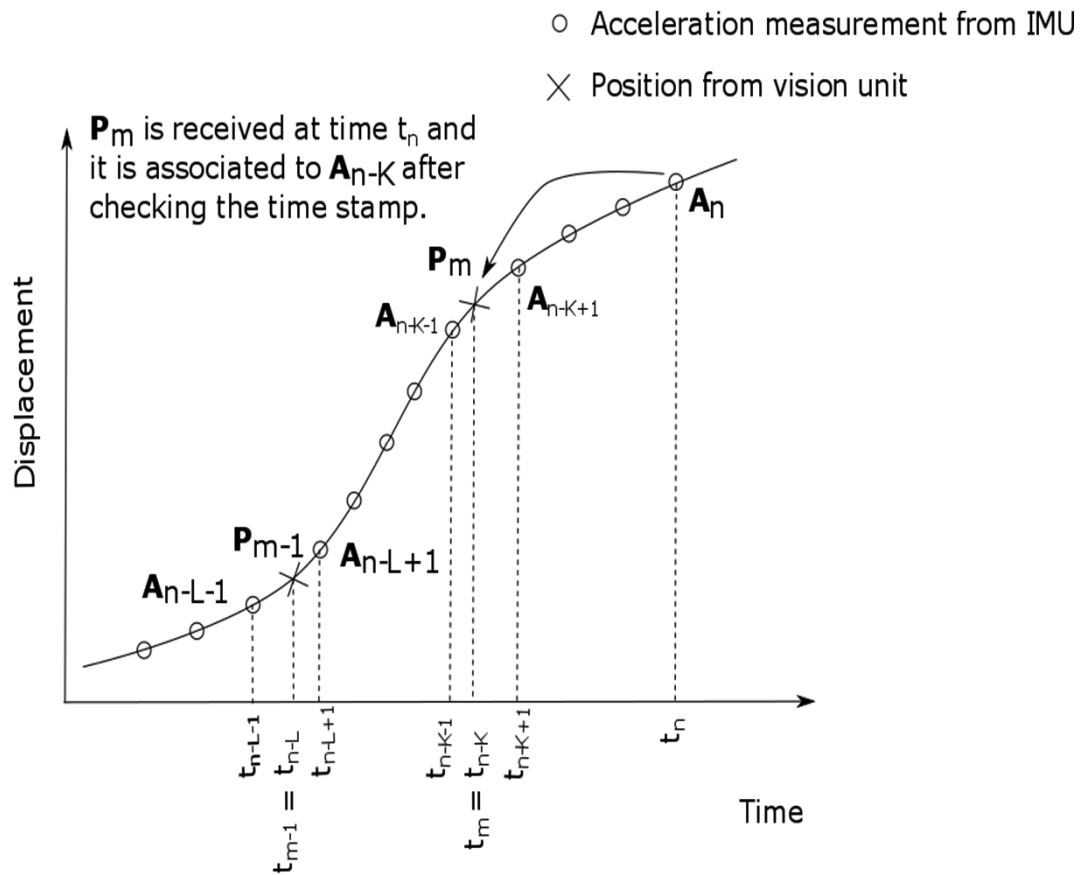
1100b

← P_{m-3}		P_{m-1}	P_m	← Position measurement
← t_{m-3}		t_{m-1}	t_m	← Time stamp

FIG. 11C

1100C





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FIG. 12A

1200a

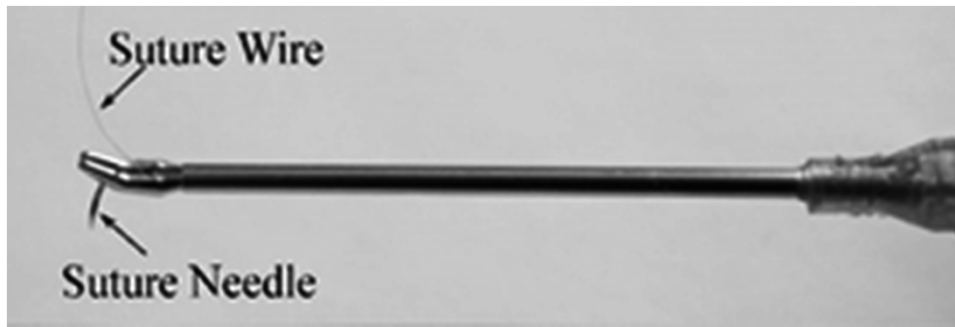


FIG. 12B

1200b



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FIG. 12C

1200c

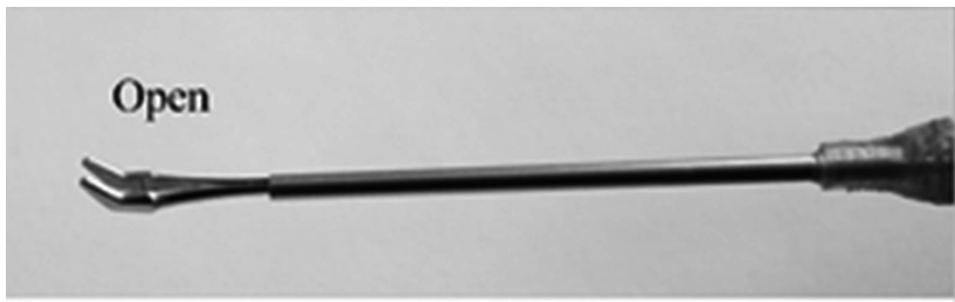
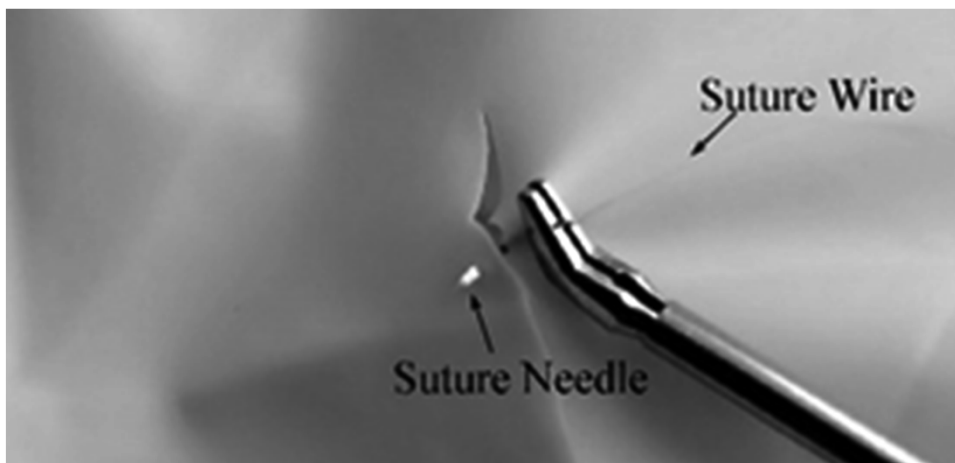


FIG. 12D

1200d



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FIG. 12E

1200e



FIG. 12F

1200f



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FIG. 13A

1300a

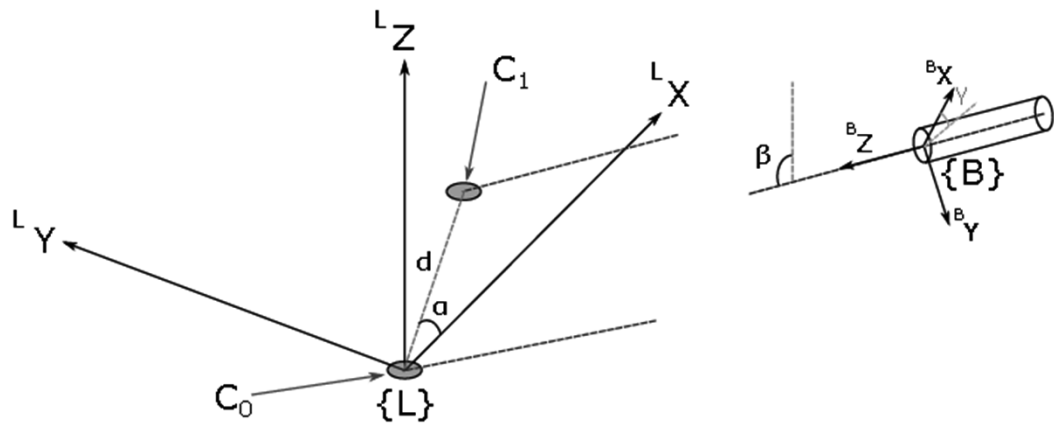
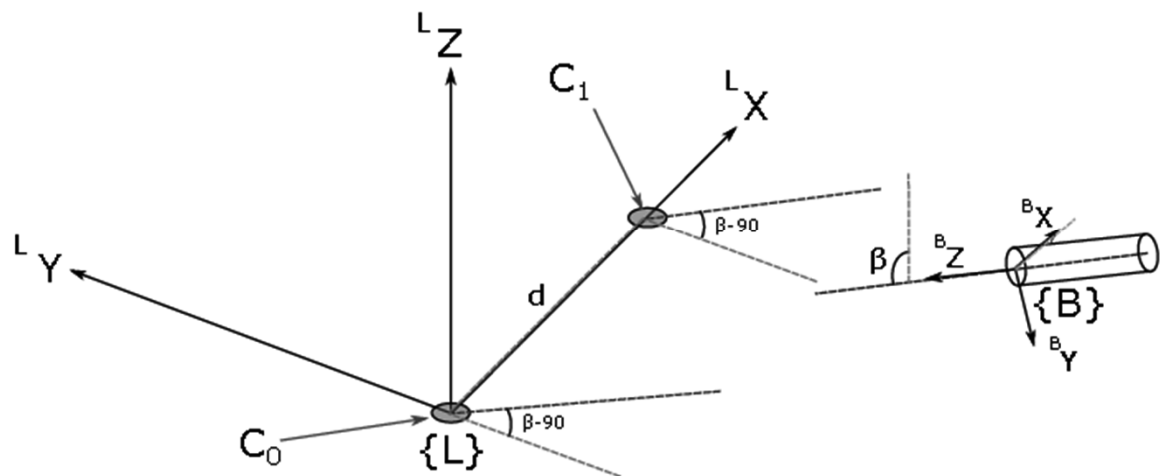


FIG. 13B

1300b



1300c

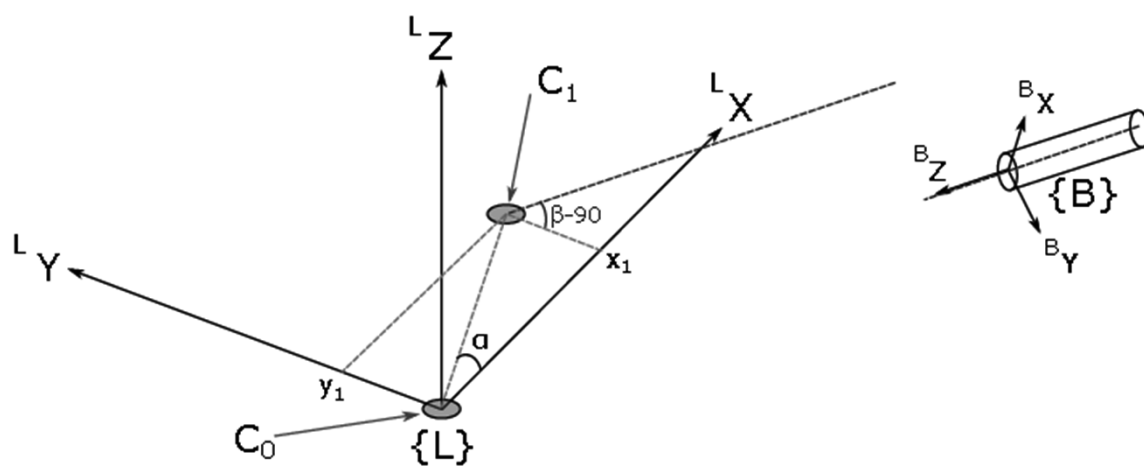
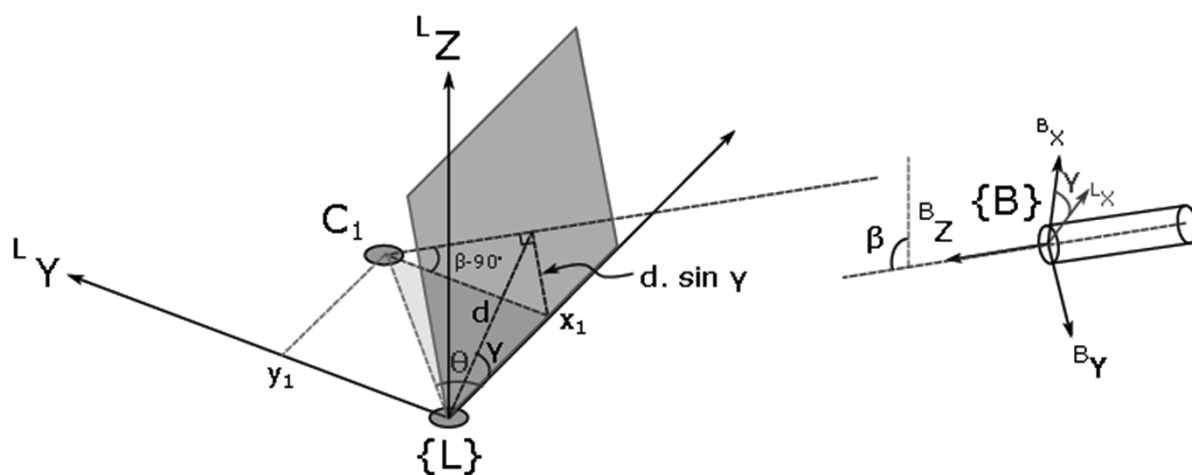


FIG. 13D

1300d



Competitive Analysis	Proposed Instrument/ System	Intuitive Surgical, Inc. (Da Vinci System)
Positioning accuracy	Max error < 100 μm ; RMS error < 20 μm	Approximate fiducial localization error (FLE): 1 mm
Cost	Initial: US\$5K Operating (per surgery): US\$500	Initial: > US\$1M Operating (per surgery): >US\$10k
Dexterity	Inherits the full dexterity of human hands	Limited by the 6 DOF arms and inertia of the arms.
Size	Small handheld instrument $\varnothing 22 \times 170 \text{mm}$, 80g	Large telerobotic arms and console

	Proposed Instrument/ System Device	CMU Device
Size & Weight	Ø22x170mm, 80g	Ø28.5x126mm, 70g
Error reduction performance	max ϵ : 253→98 μ m; 61.2% reduction rmse: 60→16 μ m; 73.3% reduction	max ϵ : 301→103 μ m; 65.7% reduction rmse: 93→40 μ m; 57.0% reduction