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(54) ULTRASONIC SCALPEL WAVEGUIDE SHAFT

(57) A waveguide rod for an ultrasonic scalpel having a relatively desirable amplitude and frequency comprises a proximal gain structure, a distal gain structure, an intermediate structure, and a frequency adjustment structure. The proximal gain structure and the intermediate structure are connected in a position near an antinode of longitudinal vibration of the waveguide rod through a proximal side gain step. The distal gain structure and the intermediate structure are connected in a position near an antinode of the longitudinal vibration of the waveguide rod through a distal side gain step. The intermediate structure comprises N (N > 0, and N is an integer) gain holding structures that are connected end-to-end in a position near an antinode of the longitudinal vibration of the waveguide rod through an intermediate gain step. X (X > 0, and X is an integer) frequency adjustment structures exist on the gain holding structure. The waveguide rod provides an ultrasonic scalpel with a relatively large blade amplitude and also enables the ultrasonic scalpel to work at a stable and suitable vibration frequency, so that the ultrasonic scalpel can cut human tissue efficiently.

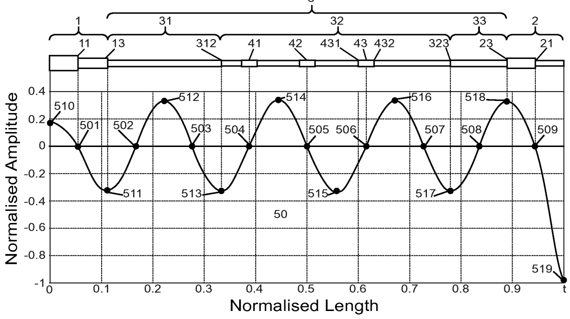

Fig.1.

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Description

Technical Field

[0001] This application relates to ultrasonic surgical instruments, and specifically, to an ultrasonic scalpel having a waveguide rod.

Background Art

[0002] In current clinical fields, due to advantages such as neat incisions, rapid hemostasis, small thermally damaged regions, and little smoke, ultrasonic scalpels have been used increasingly widely in place of conventional minimally invasive surgical instruments such as high-frequency electric scalpels and mechanical clamps. The ultrasonic scalpel uses an ultrasonic frequency generator to generate mechanical vibration in a blade at a particular ultrasonic frequency to vaporize water molecules in tissue, break hydrogen bonds in proteins, and wreck cells, so as to achieve the objective of tissue cutting, blood coagulation, and vascular closure. Related research has proved (see "Working Principles and Clinical Applications of Ultrasonic Scalpels", LIN Guoqing, QU Zhe, Chinese Medical Equipment Journal, 2008, and "Optimized Design of Ultrasonic Scalpels", ZHOU Hongsheng, XU Xiaofang, et al., Technical Acoustics, February, 2012) that when a mechanical vibration whose particle acceleration is 5x104 g (g is the gravitational acceleration) is applied on living biological tissue, the position where the mechanical vibration is applied can be cut open rapidly without damaging surrounding tissue. The relationship between the amplitude, frequency, and acceleration of a blade of an ultrasonic scalpel is: $a = A(2\pi f)2$, wherein a is the acceleration, A is the amplitude, and f is the vibration frequency. Therefore, the frequency and amplitude of vibration of the blade of the ultrasonic scalpel determine the cutting capability of the blade of the ultrasonic scalpel.

[0003] An ultrasonic scalpel generally comprises a main unit, a transducer, a waveguide rod, a blade, an auxiliary mechanism connecting and supporting the foregoing parts, and other accessories. The main unit generates a high-frequency current. The transducer converts the high-frequency current into an ultrasound vibration. Ultrasonic energy is then transferred to the blade through the waveguide rod. The blade contacts human tissue and friction is generated between the blade and the human tissue to produce effects of mechanical cutting and blood coagulation. Generally, the transducer and the waveguide rod are threaded together, and the waveguide rod and the blade may be threaded, welded or directly integrated. During normal working, the transducer, the waveguide rod, and the blade resonate at a resonant frequency. During transfer of the ultrasound vibration from the transducer to the blade through the waveguide rod, in one aspect, the vibration needs to be amplified to provide the blade with sufficient amplitude, and in another aspect, the waveguide rod is a critical factor for keeping the vibration frequency of the blade stable and suitable. Therefore, the design of the waveguide rod needs to consider both a vibration frequency and an amplitude gain. Persons skilled in the art are always seeking for a waveguide rod structure that has both a stable and suitable vibration frequency and a relatively large amplitude gain.

[0004] Patent CN200480036431.8 discloses an ultrasonic scalpel having a gain step, wherein a distance between a gain step and a vibration node on a waveguide rod is set to obtain a relatively large blade amplitude. Patent CN201410068159.7 discloses an ultrasonic scalpel having a waveguide rod with a periodically repetitive structure. The repetitive structure can enable the ultrasonic scalpel to work at a stable frequency. However, the structures disclosed in the foregoing patent deal with only one of the amplitude and the frequency of a waveguide rod rather than taking both amplitude and frequency into consideration.

Summary of This Invention

[0005] In view of the foregoing deficiencies in the prior art, this application provides a novel waveguide rod structure for an ultrasonic scalpel, so that an ultrasonic scalpel can have a relatively large blade amplitude and also can work at a stable and suitable vibration frequency. Therefore, the ultrasonic scalpel can cut human tissue efficiently.

[0006] To resolve the foregoing technical problem, the Invention adopts the following technical solution:
A waveguide rod for an ultrasonic scalpel comprises a proximal gain structure, a distal gain structure, an intermediate structure, and a frequency adjustment structure on the intermediate structure.

[0007] The proximal gain structure and the intermediate structure are connected in a position near an antinode of longitudinal vibration of the waveguide rod through a proximal side gain step.

[0008] The gain of the proximal side gain step is greater than or less than a unit gain, and the distance between the proximal side gain step and the antinode is less than 5% of a half wavelength of the longitudinal vibration of the waveguide rod. Preferably, the proximal side gain step is located in a position of the antinode.

[0009] The distal gain structure and the intermediate structure are connected in a position near an antinode of the longitudinal vibration of the waveguide rod through a distal side gain step. The gain of the distal side gain step is greater than or less than a unit gain, and the distance between the distal side gain step and the antinode is less than 5% of a half wavelength of the longitudinal vibration of the waveguide rod. Preferably, the distal side gain step is located in the position of the antinode.

[0010] One or more proximal gain steps exist on the proximal gain structure, the gain of the proximal gain step is greater than a unit gain, the proximal gain step is in a position near a node of the longitudinal vibration of the waveguide rod, only zero or at most one proximal gain step exists in a position near each node, and the distance between the proximal gain step and the node is less than 5% of a half wavelength of the longitudinal vibration of the waveguide rod. Preferably, the proximal gain step is located in the position of a node.

[0011] One or more distal gain steps exist on the distal gain structure, the gain of the distal gain step is greater than a unit gain, the distal gain step is in a position near a node of the longitudinal vibration of the waveguide rod, only zero or at most one distal gain step exists in a position near each node, and the distance between the distal gain step and the node is less than 5% of a half wavelength of the longitudinal vibration of the waveguide rod. Preferably, the distal gain step is located in a position of a node.

[0012] The intermediate structure comprises N (N > 0, and N is an integer) gain holding structures that are connected end-to-end at positions near antinodes of the longitudinal vibration of the waveguide rod through an intermediate gain step, and the distance between each intermediate gain step and the antinode is less than 5% of a half wavelength of the longitudinal vibration of the waveguide rod. Preferably, the intermediate gain step is located in a position of the antinode.

[0013] The frequency adjustment structure is disposed on the gain holding structure of the intermediate structure. A quantity of frequency adjustment structures is X (X > 0, and X is an integer), and each frequency adjustment structure forms a front frequency modulation gain step and a rear frequency modulation gain step on a gain holding structure.

[0014] Only one node of the longitudinal vibration of the waveguide rod exists between the front frequency modulation gain step and the rear frequency modulation gain step, the distance between the front frequency modulation gain step and the rear frequency modulation gain step is less than the distance between two antinodes of the longitudinal vibration that are adjacent to a node, and one of the gains of the front frequency modulation gain step and the rear frequency modulation gain step is greater than a unit gain and the other of the gains is less than the unit gain.

[0015] According to this application, preferred implementation solutions of the proximal gain structure and the distal gain structure are:

1) The proximal gain structure is located in a range of a first half wavelength of the longitudinal vibration of the waveguide rod, and the proximal gain step is in a position near the first node of the longitudinal vibration of the waveguide rod.
2) The proximal gain structure is located in a range of first two half wavelengths of the longitudinal vibration of the waveguide rod, and the proximal gain step is in a position near the first or second node of the longitudinal vibration of the waveguide rod.
3) The distal gain structure is located in a range of the last half wavelength of the longitudinal vibration of the waveguide rod, and the distal gain step is in a position near the last node of the longitudinal vibration of the waveguide rod.
4) The distal gain structure is located in a range of last two half wavelengths of the longitudinal vibration of the waveguide rod, and the distal gain step is in a position near the last or the second last node of the longitudinal vibration of the waveguide rod. In addition, another implementation solution of the proximal gain structure and the distal gain structure that meets a requirement of this application is also protected by the Invention.

[0016] Further, a plurality of preferred implementation forms is used to implement that the intermediate structure comprises N (N > 0, and N is an integer) gain holding structures that are connected end-to-end in positions near antinodes of the longitudinal vibration of the waveguide rod through an intermediate gain step.

1) The number N of gain holding structures on the intermediate structure is equal to 1.
2) The number N of gain holding structures on the intermediate structure is greater than 1, N is an odd number, and a gain sequence of the intermediate gain steps connecting the gain holding structures is: a gain of each of a first intermediate gain step to an ((N-1)/2)th intermediate gain step is greater than a unit gain, and a gain of each of an ((N-1)/2+1)th intermediate gain step to an (N-1)th intermediate gain step is less than the unit gain.
3) The number N of gain holding structures on the intermediate structure is greater than 1, N is an odd number, and a gain sequence of the intermediate gain steps connecting the gain holding structures is: a gain of each of a first intermediate gain step to an ((N-1)/2)th intermediate gain step is less than a unit gain, and a gain of each of an ((N-1)/2+1)th intermediate gain step to an (N-1)th intermediate gain step is greater than the unit gain.
4) The number N of gain holding structures on the intermediate structure is greater than 1, N is an odd number, and a gain sequence of the intermediate gain steps connecting the gain holding structures is formed by sequentially and alternately arranging a gain greater than a unit gain and a gain less than a unit gain.
5) The number N of gain holding structures on the intermediate structure is greater than 1, N is an odd number, and a gain sequence of the intermediate gain steps connecting the gain holding structures is formed by sequentially and alternately arranging a gain less than a unit gain and a gain greater than a unit gain.
6) The number N of gain holding structures is equal to 2, and the gain of an intermediate gain step con-

necting two gain holding structures is greater than a unit gain.

7) The number N of gain holding structures is equal to 2, and a gain of an intermediate gain step connecting two gain holding structures is less than a unit gain.

8) The number N of gain holding structures is greater than 2, N is an even number, and a gain sequence of the intermediate gain steps connecting the gain holding structures is formed by sequentially and alternately arranging a gain greater than a unit gain and a gain less than a unit gain. 9) The number N of gain holding structures is greater than 2, N is an even number, and a gain sequence of the intermediate gain steps connecting the gain holding structures is formed by sequentially and alternately arranging a gain less than a unit gain and a gain greater than a unit gain. In addition, another implementation solution of the intermediate structure that meets a requirement of this application is also protected by the Invention.

[0017] Further, one or more frequency adjustment structures exist on some gain holding structures, and the frequency adjustment structure has two implementation forms: 1) For the front frequency modulation gain step and the rear frequency modulation gain step of the frequency adjustment structure, the gain of the front frequency modulation gain step is less than a unit gain, and the gain of the rear frequency modulation gain step is greater than a unit gain. 2) For the front frequency modulation gain step and the rear frequency modulation gain step of the frequency adjustment structure, the gain of the front frequency modulation gain step is greater than a unit gain, and the gain of the rear frequency modulation gain step is less than a unit gain.

[0018] In specific implementation manners of the waveguide rod for an ultrasonic scalpel, the Invention comprises different implementation manners of the foregoing proximal gain structure, distal gain structure, intermediate structure, and frequency adjustment structure.

[0019] The foregoing gain steps may have a form selected from a step shape, a conical form, an exponential form or a catenary form.

[0020] Several benefits can be obtained from one or more implementation forms of the Invention. The waveguide rod for an ultrasonic scalpel of the Invention comprises a proximal gain structure, a distal gain structure, an intermediate structure, and a frequency adjustment structure. The proximal gain structure has a proximal gain step whose gain is greater than a unit gain in a position near a node of longitudinal vibration of the waveguide rod. It is known to persons skilled in the art that a gain step in a position near a node can affect an amplitude gain significantly, wherein a gain step whose gain is greater than a unit gain can effectively amplify an amplitude, and a gain step whose gain is less than a unit gain can effectively attenuate an amplitude. Therefore, the proximal gain structure can provide the waveguide rod with a relatively large initial amplitude gain. Gain holding structures on the intermediate structure are connected end-to-end at positions near antinodes of the longitudinal vibration of the waveguide rod through an intermediate gain step. It is known to persons skilled in the art that a gain step in a position near an antinode affects an amplitude gain relatively slightly. Therefore, the intermediate structure can ensure that the amplitude of ultrasound is basically not attenuated or amplified during propagation of the ultrasound in the intermediate structure of the waveguide rod. Without attenuation, the effectiveness of amplitude amplification of the proximal gain structure can be kept. Without amplification, a loss during energy transfer can be reduced. Similar to the proximal gain structure, the distal gain structure has a distal gain step whose gain is greater than a unit gain in a position near a node of the longitudinal vibration of the waveguide rod, so that the waveguide rod can be provided with a relatively large secondary amplitude gain. In this way, the waveguide rod uses the proximal gain structure to provide a relatively large initial amplitude gain, uses the intermediate structure to basically hold the amplitude without attenuation and amplification, and then uses the distal gain structure to provide a relatively large secondary amplitude gain, so as to eventually provide a relatively large amplitude for the vibration of a blade. The frequency adjustment structure exists on some gain holding structures of the intermediate structure. The frequency adjustment structure is disposed in a position near a node of the longitudinal vibration of the waveguide rod, and two frequency modulation gain steps are formed before and after the node, wherein the gain of one frequency modulation gain step is greater than a unit gain, and the gain of the other frequency modulation gain step is less than a unit gain. Such a structural form only affects an amplitude gain relatively slightly but can effectively adjust a vibration frequency of the waveguide rod, so that the vibration frequency of the waveguide rod is stabilized in a suitable range. In this way, the waveguide rod that comprises the proximal gain structure, the distal gain structure, the intermediate structure, and the frequency adjustment structure can provide an ultrasonic scalpel with a relatively large amplitude during working and also can enable the ultrasonic scalpel to work stably at a suitable working frequency, so that human tissue can be cut efficiently.

Brief Description of the Drawings

[0021]

Fig. 1 shows a waveguide rod for an ultrasonic scalpel according to a first implementation manner of this application and a waveform generated along the waveguide rod.

Fig. 2 shows a waveguide rod for an ultrasonic scalpel according to a second implementation manner of this application and a waveform generated along the waveguide rod.

Fig. 3 shows a waveguide rod for an ultrasonic scalpel according to a third implementation manner of this application and a waveform generated along the waveguide rod.

Fig. 4 shows a waveguide rod for an ultrasonic scalpel according to a fourth implementation manner of this application and a waveform generated along the waveguide rod.

Fig. 5 shows a waveguide rod for an ultrasonic scalpel according to a fifth implementation manner of this application and a waveform generated along the waveguide rod.

Detailed Description of Embodiments

[0022] Referring to Fig. 1, Fig. 1 shows a waveguide rod for an ultrasonic scalpel according to a first implementation manner of this application and a waveform generated along the waveguide rod. The waveguide rod for an ultrasonic scalpel comprises a proximal gain structure 1, a distal gain structure 2, an intermediate structure 3, and frequency adjustment structures 41, 42, and 43. A curve 50 below the waveguide rod in Fig. 1 is an amplitude curve of longitudinal vibration of the waveguide rod, wherein the horizontal axis is the normalized length, and the vertical axis is the normalized amplitude. In the curve 50, 501 to 509 are nodes of the longitudinal vibration. The node 501 is the first node, the node 509 is the last node, and 510 to 519 are antinodes of the longitudinal vibration. The antinode 510 is the first antinode, and the antinode 519 is the last antinode. The proximal gain structure 1 and the intermediate structure 3 are connected through a proximal side gain step 13. The position of the proximal side gain step 13 is near the second antinode 511 of the longitudinal vibration, and the gain of the proximal side gain step 13 is greater than a unit gain. The distal gain structure 2 and the intermediate structure 3 are connected through a distal side gain step 23. The position of the distal side gain step 23 is near the second last antinode 518 of the longitudinal vibration, and the gain of the distal side gain step 23 is less than a unit gain.

[0023] The proximal gain structure 1 has a most proximal gain step 11 in a position near the first node 501 of the longitudinal vibration of the waveguide rod. The gain of the most proximal gain step 11 is greater than a unit gain. That is, the most proximal gain step 11 is an amplification step. The distal gain structure 2 has a most distal gain step 21 in a position near the last node 509 of the longitudinal vibration of the waveguide rod. The gain of the most distal gain step 21 is greater than a unit gain. That is, the most distal gain step 21 is an amplification step. The proximal gain structure 1 and the distal gain structure 2 set gain steps (that is, the most proximal gain step 11 and the most distal gain step 21) thereof in positions near a node, so that an amplitude gain can be effectively improved. An eventual amplitude gain of the entire waveguide rod is also mainly determined by the gains of the proximal gain structure 1 and the distal gain structure 2. As shown in Fig. 1, the most proximal gain step 11 enables an amplitude gain between the second antinode 511 and the first antinode 510 to be approximately 1.9, and the most distal gain step 21 enables an amplitude gain between the last antinode 519 and the second last antinode 518 to be approximately 3, so that the eventual amplitude gain of the waveguide rod can be up to 5.7. In this way, a relatively large amplitude can be generated in a blade of an ultrasonic scalpel.

[0024] The intermediate structure of the waveguide rod 3 comprises N (N > 0, and N is an integer) gain holding structures, and comprises three gain holding structures 31, 32, and 33 in the implementation manner in Fig. 1. The first gain holding structure 31 and the second gain holding structure 32 are connected through an intermediate gain step 312. The position of the intermediate gain step 312 is near the fourth antinode 513 of the longitudinal vibration, and the gain of the intermediate gain step 312 is greater than a unit gain. The second gain holding structure 32 and the third gain holding structure 33 are connected through an intermediate gain step 323. The position of the intermediate gain step 323 is near the third last antinode 517 of the longitudinal vibration, and the gain of the intermediate gain step 323 is less than a unit gain. The applicant finds that the arrangement that the gain holding structures 31, 32, and 33 are connected end-to-end through gain steps in positions near antinodes of the longitudinal vibration can ensure that the amplitude of an ultrasound vibration is basically not attenuated or amplified during propagation of the ultrasound vibration in the intermediate structure of the waveguide rod, so as to facilitate more stable transfer of energy to the blade.

[0025] In some gain holding structures of the intermediate structure 3, in the implementation manner shown in the intermediate structure 3, the frequency adjustment structures 41, 42, and 43 are further disposed on the second gain holding structure 32. Each frequency adjustment structure has a front frequency modulation gain step and a rear frequency modulation gain step. Referring to Fig. 1, the frequency adjustment structure 43 is used as an example. The frequency adjustment structure 43 forms a front frequency modulation gain step 431 and a rear frequency modulation gain step 432 on the gain holding structure 32. The gain of the front frequency modulation gain step 431 is less than a unit gain, and the gain of the rear frequency modulation gain step 432 is greater than a unit gain. Only one node 506 of the longitudinal vibration of the waveguide rod exists between the front frequency modulation gain step 431 and the rear frequency modulation gain step 432. The distance between the front frequency modulation gain step and the rear frequency modulation gain step is less than the distance between the two antinodes 515 and 516 of the longitudinal vibration adjacent to the node 506. The applicant finds that the vibration frequency of the waveguide rod can be adjusted by increasing or reducing the number of frequency adjustment structures, increasing or reducing the distance between a front gain step and a rear gain step of the frequency adjustment structure or increasing or reducing gains of the front gain step and the rear gain step, basically without affecting the amplitude eventually output by the waveguide rod. The foregoing frequency adjustment structures 41, 42, and 43 keep a resonance frequency of the waveguide rod in a required range, so that the ultrasonic scalpel can work stably at a suitable frequency.

[0026] According to the structural form in Fig. 1 of this application, the proximal gain structure 1 and the distal gain structure 2 provide a relatively large amplitude gain, so as to provide a relatively large amplitude for a vibration of the blade of the ultrasonic scalpel. The gain holding structures 31, 32, and 33 on the intermediate structure 3 can ensure that the amplitude of an ultrasound vibration is basically not attenuated or amplified during propagation of the ultrasound vibration in the intermediate structure of the waveguide rod. The frequency adjustment structures 41, 42, and 43 stabilize the vibration frequency of the waveguide rod in a suitable range. In this way, the ultrasonic scalpel can be provided with a relatively large amplitude during working and also can work stably at a suitable frequency, so that human tissue can be cut efficiently.

[0027] Fig. 2 shows a waveguide rod for an ultrasonic scalpel according to a second implementation manner of this application and a waveform generated along the waveguide rod. The implementation manner comprises a proximal gain structure 1, a distal gain structure 2, an intermediate structure 3, and a frequency adjustment structure 4. The proximal gain structure is in a range of a first half wavelength of longitudinal vibration of the waveguide rod, and the most proximal gain step is near the first node of the longitudinal vibration. The distal gain structure is in a range of a last half wavelength of the longitudinal vibration of the waveguide rod, and the most distal gain step is near the last node of the longitudinal vibration. The proximal gain structure and the intermediate structure are connected in a position near the second antinode of the longitudinal vibration of the waveguide rod, and the gain of a proximal side gain step is greater than a unit gain. The distal gain structure and the intermediate structure are connected in a position near the second last antinode of the longitudinal vibration of the waveguide rod, and the gain of a distal side gain step is less than a unit gain. The intermediate structure in the implementation manner comprises only one gain holding structure. One frequency adjustment structure exists on the gain holding structure. The gain of the front frequency modulation gain step of the frequency adjustment structure is less than a unit gain, and the gain of the rear frequency modulation gain step is greater than a unit gain.

[0028] Fig. 3 shows a waveguide rod for an ultrasonic scalpel according to a third implementation manner of this application and a waveform generated along the waveguide rod. The implementation manner comprises a proximal gain structure 1, a distal gain structure 2, an intermediate structure 3, and a frequency adjustment structure 4. The proximal gain structure is in a range of a first half wavelength of longitudinal vibration of the waveguide rod, and the most proximal gain step is near the first node of the longitudinal vibration. The distal gain structure is in a range of a last half wavelength of the longitudinal vibration of the waveguide rod, and the most distal gain step is near the last node of the longitudinal vibration. The proximal gain structure and the intermediate structure are connected in a position near the second antinode of the longitudinal vibration of the waveguide rod, and the gain of the proximal side gain step is greater than a unit gain. The distal gain structure and the intermediate structure are connected in a position near the second last antinode of the longitudinal vibration of the waveguide rod, and the gain of the distal side gain step is less than a unit gain. The intermediate structure in the implementation manner comprises three gain holding structures 31, 32, and 33, the gain of a first intermediate gain step is less than the unit gain, and the gain of a second intermediate gain step is greater than a unit gain. One frequency adjustment structure 4 exists on the gain holding structure 32 in the middle. The gain of the front frequency modulation gain step of the frequency adjustment structure is greater than a unit gain, and the gain of the rear frequency modulation gain step is less than a unit gain.

[0029] Fig. 4 shows a waveguide rod for an ultrasonic scalpel according to a fourth implementation manner of this application and a waveform generated along the waveguide rod. The implementation manner comprises a proximal gain structure 1, a distal gain structure 2, an intermediate structure 3, and a frequency adjustment structure 4. The proximal gain structure is a range of a first half wavelength of longitudinal vibration of the waveguide rod, and the most proximal gain step is near the first node of the longitudinal vibration. The distal gain structure is in a range of a last half wavelength of the longitudinal vibration of the waveguide rod, and the most distal gain step is near the last node of the longitudinal vibration. The proximal gain structure and the intermediate structure are connected in a position near the second antinode of the longitudinal vibration of the waveguide rod, and the gain of a proximal side gain step is greater than a unit gain. The distal gain structure and the intermediate structure are connected in a position near the second last antinode of the longitudinal vibration of the waveguide rod, and the gain of a distal side gain step is greater than a unit gain. The intermediate structure in the implementation manner comprises four gain holding structures 31, 32, 33, and 34, and a gain sequence of the intermediate gain steps is formed by alternately arranging a gain less than a unit gain and a gain greater than a unit gain. One frequency adjustment structure 4 exists on the second gain holding structure 32. The gain of the front frequency modulation gain step of the frequency adjustment structure is greater than a unit gain, and the gain of the rear frequency modulation gain step is less than a unit gain.

[0030] Fig. 5 shows a waveguide rod for an ultrasonic scalpel according to a fifth implementation manner of this application and a waveform generated along the waveguide rod. The implementation manner comprises a proximal gain structure 1, a distal gain structure 2, an intermediate structure 3, and a frequency adjustment structure 4. The proximal gain structure is in a range of first two half wavelengths of longitudinal vibration of the waveguide rod, with two proximal gain steps respectively near the first node and the second node of the longitudinal vibration. The distal gain structure is in a range of the last half wavelength of the longitudinal vibration of the waveguide rod, and the most distal gain step is near the last node of the longitudinal vibration. The proximal gain structure and the intermediate structure are connected in a position near the third antinode of the longitudinal vibration of the waveguide rod, and the gain of the proximal side gain step is greater than a unit gain. The distal gain structure and the intermediate structure are connected in a position near the second last antinode of the longitudinal vibration of the waveguide rod, and the gain of a distal side gain step is less than a unit gain. The intermediate structure in the implementation manner comprises only one gain holding structure. One frequency adjustment structure exists on the gain holding structure, the gain of the front frequency modulation gain step of the frequency adjustment structure is less than a unit gain, and the gain of the rear frequency modulation gain step is greater than a unit gain.

[0031] It should be noted that the gain steps in the examples of this application all have a step shape. However, the shape of the gain steps is not limited in this application. Common gain step types such as a conical form, an exponential form, and a catenary form all fall within the protection scope of this application. In addition, the implementation solutions in Fig. 1 to Fig. 5 are only several relatively representative embodiments of this application. Persons skilled in the art may easily understand that the protection scope of this application is not merely limited to the ranges defined in the implementation manners, and combinations, deformations, and changes made to the implementation manners all fall within the protection scope of this application.

Claims

1. A waveguide rod for an ultrasonic scalpel, wherein the waveguide rod comprises a proximal gain structure, a distal gain structure, an intermediate structure, and a frequency adjustment structure located on the intermediate structure, wherein
the proximal gain structure and the intermediate structure are connected in a position near an antinode of longitudinal vibration of the waveguide rod through a proximal side gain step;
the distal gain structure and the intermediate structure are connected in a position near an antinode of the longitudinal vibration of the waveguide rod through a distal side gain step;
the intermediate structure comprises N (N > 0, and N is an integer) gain holding structures, and when N > 1, the gain holding structures are connected end-to-end in positions near antinodes of the longitudinal vibration of the waveguide rod through an intermediate gain step; and
the frequency adjustment structure is disposed on the gain holding structure, and the number of frequency adjustment structures is X (X > 0, and X is an integer).

2. The waveguide rod according to claim 1, wherein the gain of the proximal side gain step is greater than or less than a unit gain, and the distance between the proximal side gain step and the antinode is less than 5% of a half wavelength of the longitudinal vibration of the waveguide rod.

3. The waveguide rod according to claim 2, wherein the proximal side gain step is located in a position of an antinode of the longitudinal vibration of the waveguide rod.

4. The waveguide rod according to claim 1, wherein the gain of the distal side gain step is greater than or less than a unit gain, and the distance between the distal side gain step and the antinode is less than 5% of a half wavelength of the longitudinal vibration of the waveguide rod.

5. The waveguide rod for an ultrasonic scalpel according to claim 4, wherein the distal side gain step is located in a position of an antinode of the longitudinal vibration of the waveguide rod.

6. The waveguide rod for an ultrasonic scalpel according to claim 1, wherein the proximal gain structure is located in a range of a first half wavelength or a range of first two half wavelengths of the longitudinal vibration of the waveguide rod.

7. The waveguide rod for an ultrasonic scalpel according to claim 1, wherein the distal gain structure is located in a range of a last half wavelength or a range of last two half wavelengths of the longitudinal vibration of the waveguide rod.

8. The waveguide rod according to claim 1, wherein

one or more proximal gain steps exist in a position near a node of the longitudinal vibration of the waveguide rod on the proximal gain structure, only zero or one proximal gain step exists in a position near each node, the distance between the proximal gain step and the node is less than 5% of a half wavelength of the longitudinal vibration of the waveguide rod, and the gain of the proximal gain step is greater than a unit gain.

9. The waveguide rod according to claim 8, wherein the proximal gain step is located in a position of a node of the longitudinal vibration of the waveguide rod.

10. The waveguide rod according to claim 1, wherein one or more distal gain steps exist in a position near a node of the longitudinal vibration of the waveguide rod on the distal gain structure, only zero or one distal gain step exists in a position near each node, the distance between the distal gain step and the node is less than 5% of a half wavelength of the longitudinal vibration of the waveguide rod, and the gain of the distal gain step is greater than a unit gain.

11. The waveguide rod for an ultrasonic scalpel according to claim 10, wherein the distal gain step is located in a position of a node of the longitudinal vibration of the waveguide rod.

12. The waveguide rod for an ultrasonic scalpel according to claim 1, wherein the distance between each intermediate gain step and the antinode of the longitudinal vibration of the waveguide rod is less than 5% of a half wavelength of the longitudinal vibration of the waveguide rod.

13. The waveguide rod for an ultrasonic scalpel according to claim 12, wherein the intermediate gain step is located in a position of the antinode of the longitudinal vibration of the waveguide rod.

14. The waveguide rod for an ultrasonic scalpel according to claim 1, wherein the number N of the gain holding structures on the intermediate structure is equal to 1.

15. The waveguide rod for an ultrasonic scalpel according to claim 1, wherein the number N of the gain holding structures on the intermediate structure is greater than 1, and N is an odd number.

16. The waveguide rod for an ultrasonic scalpel according to claim 15, wherein a gain sequence of the intermediate gain steps connecting the gain holding structures is: the gain of each of a first intermediate gain step to an ((N-1)/2)th intermediate gain step is greater than a unit gain, and the gain of each of an ((N-1)/2+1)th intermediate gain step to an (N-1)th intermediate gain step is less than a unit gain.

17. The waveguide rod for an ultrasonic scalpel according to claim 15, wherein a gain sequence of the intermediate gain steps connecting the gain holding structures is: the gain of each of a first intermediate gain step to an ((N-1)/2)th intermediate gain step is less than a unit gain, and the gain of each of an ((N-1)/2+1)th intermediate gain step to an (N-1)th intermediate gain step is greater than a unit gain.

18. The waveguide rod for an ultrasonic scalpel according to claim 15, wherein a gain sequence of the intermediate gain steps connecting the gain holding structures is formed by sequentially and alternately arranging a gain greater than a unit gain and a gain less than a unit gain.

19. The waveguide rod for an ultrasonic scalpel according to claim 15, wherein a gain sequence of the intermediate gain steps connecting the gain holding structures is formed by sequentially and alternately arranging a gain less than a unit gain and a gain greater than a unit gain.

20. The waveguide rod for an ultrasonic scalpel according to claim 1, wherein the number N of the gain holding structures is equal to 2.

21. The waveguide rod for an ultrasonic scalpel according to claim 20, wherein the gain of an intermediate gain step connecting two gain holding structures is greater than a unit gain.

22. The waveguide rod for an ultrasonic scalpel according to claim 20, wherein the gain of an intermediate gain step connecting two gain holding structures is less than a unit gain.

23. The waveguide rod for an ultrasonic scalpel according to claim 1, wherein the number N of the gain holding structures is greater than 2, and N is an even number.

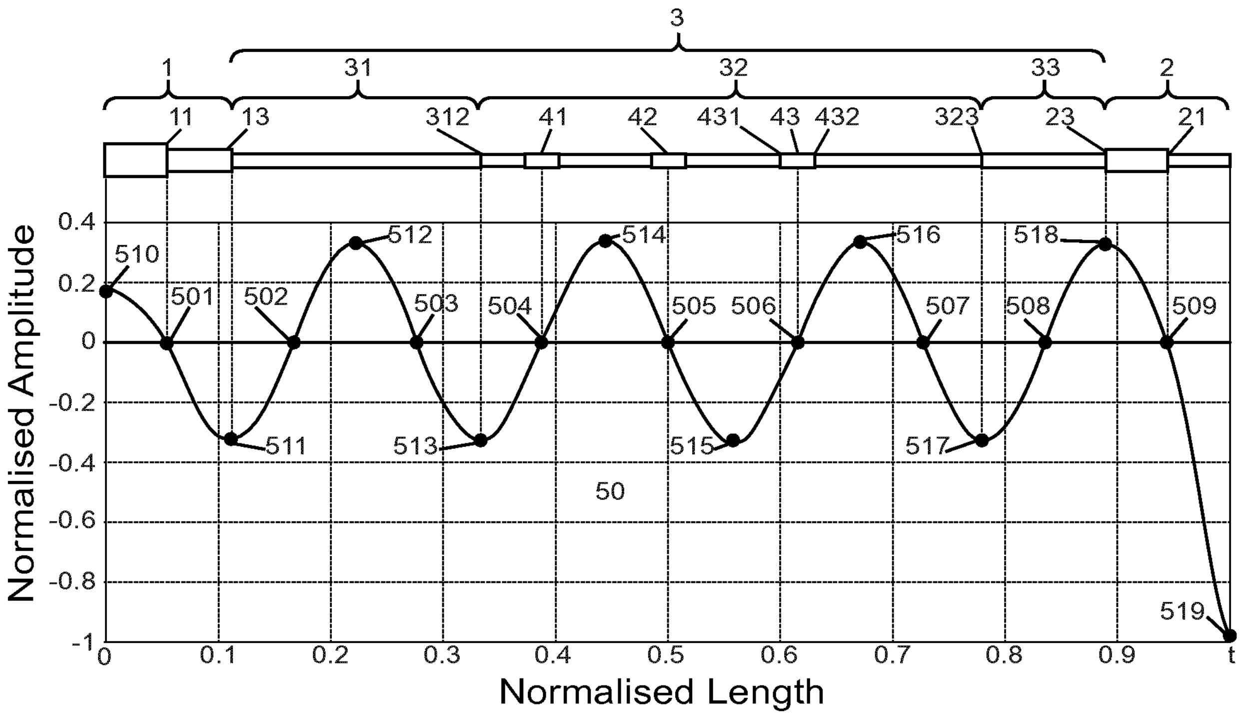
24. The waveguide rod for an ultrasonic scalpel according to claim 23, wherein a gain sequence of the intermediate gain steps connecting the gain holding structures is formed by sequentially and alternately arranging a gain greater than a unit gain and a gain less than a unit gain.

25. The waveguide rod for an ultrasonic scalpel according to claim 23, wherein a gain sequence of the intermediate gain steps connecting the gain holding structures is formed by sequentially and alternately arranging a gain less than a unit gain and a gain greater than a unit gain.

26. The waveguide rod according to claim 1, wherein each frequency adjustment structure forms a front frequency modulation gain step and a rear frequency modulation gain step on a gain holding structure, only one node of the longitudinal vibration of the waveguide rod exists between the front frequency modulation gain step and the rear frequency modulation gain step, the distance between the front frequency modulation gain step and the rear frequency modulation gain step is less than the distance between two antinodes of the longitudinal vibration that are adjacent to a node, and one of the gains of the front frequency modulation gain step and the rear frequency modulation gain step is greater than a unit gain and the other of the gains is less than a unit gain.

27. The waveguide rod for an ultrasonic scalpel according to claim 26, wherein for the front frequency modulation gain step and the rear frequency modulation gain step of the frequency adjustment structure, the gain of the front frequency modulation gain step is less than a unit gain, and the gain of the rear frequency modulation gain step is greater than a unit gain.

28. The waveguide rod for an ultrasonic scalpel according to claim 26, wherein for the front frequency modulation gain step and the rear frequency modulation gain step of the frequency adjustment structure, the gain of the front frequency modulation gain step is greater than a unit gain, and the gain of the rear frequency modulation gain step is less than a unit gain.



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517
50
519
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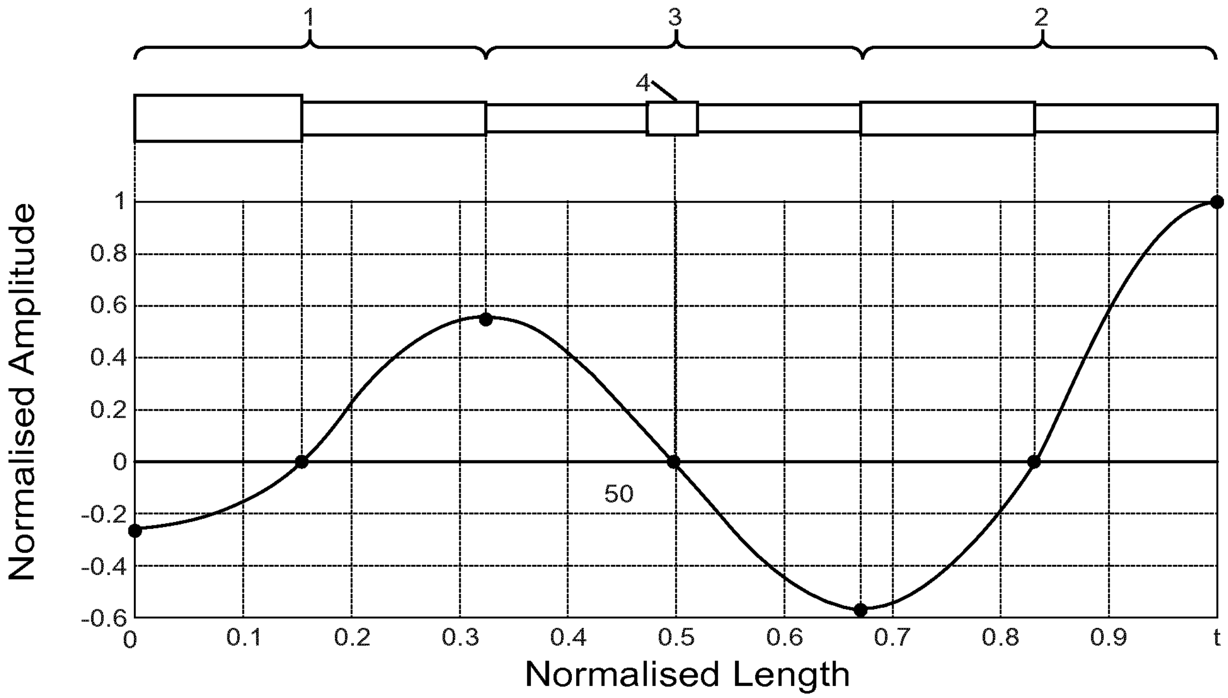
0.8
0.9
t
Normalised Length

Fig.1.



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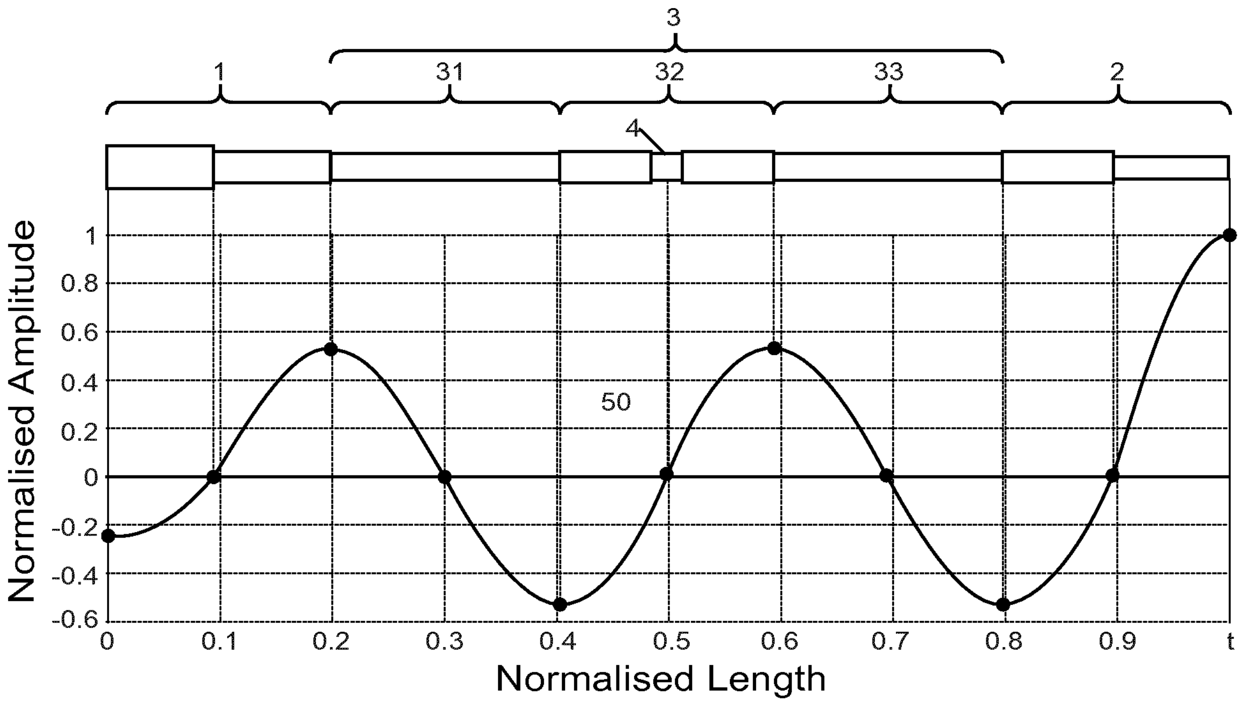
Normalised Length

Fig.2.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-0.6
50
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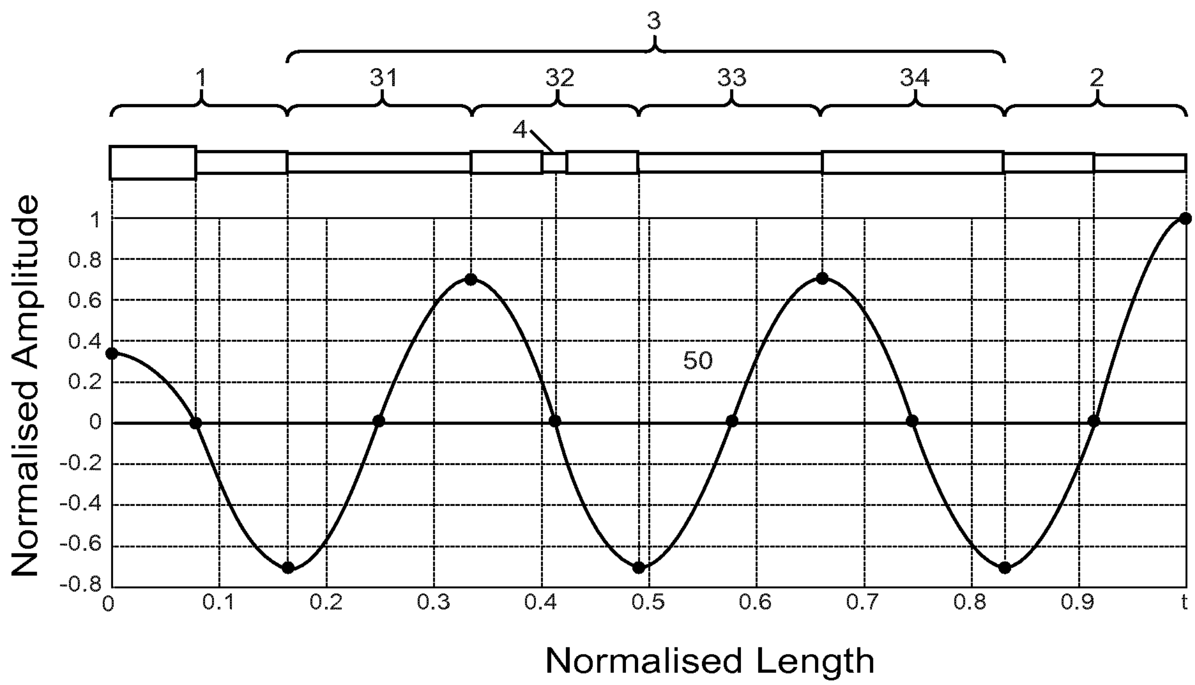
0.8
0.9
t
Normalised Length

Fig.3.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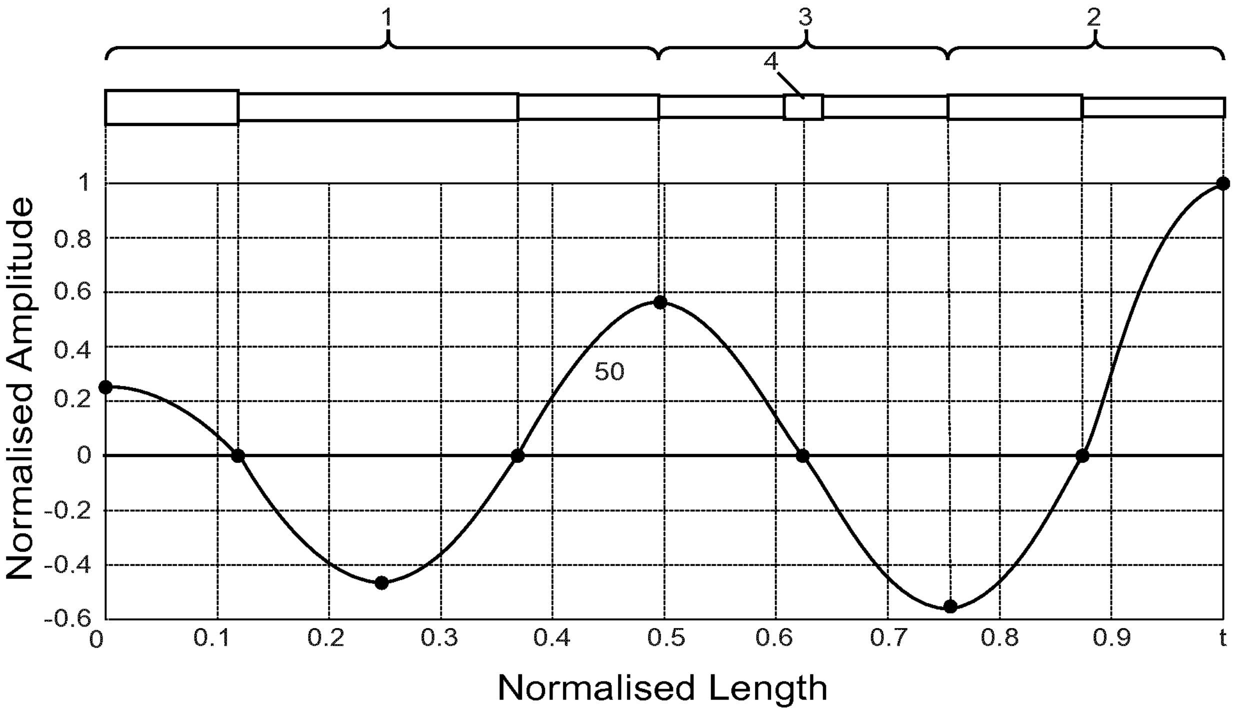
Normalised Length

Fig.4.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t
Normalised Length

Fig.5.

INTERNATIONAL SEARCH REPORT

International application No. PCT/CN2017/090329

A. CLASSIFICATION OF SUBJECT MATTER

A61B 17/3211 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61B 17

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

VEN, SIPOABS, USTXT, CNABS, CNTXT, CNKI: waveguide, step, gain, node, antinode, amplify, frequency, ultrasound, trough of wave, diameter, wave loop, wave peak, amplitude, stable

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 105962996 A (SHANGHAI YISI MEDICAL CO., LTD. et al.) 28 September 2016 (28.09.2016) claims 1-28	1-28
E	CN 206285143 U (SHANGHAI YISI MEDICAL CO., LTD. et al.) 30 June 2017 (30.06.2017) claims 1-28	1-28
Y	CN 101495050 A (ETHICON END SURGERY INC.) 29 July 2009 (29.07.2009) description, pages 11-14, and figures 1-3c	1-28
Y	CN 1684635 A (ETHICON END SURGERY INC.) 19 October 2005 (19.10.2005) description, pages 6-9, and figures 1-3a	1-28
A	WO 9816157 A1 (ETHICON ENDO SURGERY INC) 23 April 1998 (23.04.1998) the whole document	1-28
A	US 2002124617 A1 (ROBERT A et al.) 12 September 2002 (12.09.2002) the whole document	1-28

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 September 2017	11 October 2017

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Form PCT/ISA /210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT	International application No. PCT/CN2017/090329

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 104027156 A (SHANGHAI ACOUSTICS LABORATORY, CHINESE ACADEMY OF SCIENCE et al.) 10 September 2014 (10.09.2014) the whole document	1-28

Form PCT/ISA /210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2017/090329

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 105962996 A	28 September 2016	None	
CN 206285143 U	30 June 2017	None	
CN 101495050 A	29 July 2009	US 8435258 B2	07 May 2013
		JP 5323689 B2	23 October 2013
		EP 2074955 B1	10 July 2013
		AU 2007256948 B2	31 May 2012
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		EP 2029034 A4	02 June 2010
		EP 2074955 A2	01 July 2009
		US 2007282335 A1	06 December 2007
		EP 2029034 B8	14 September 2016
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Form PCT/ISA /210 (patent family annex) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2017/090329

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
		CN 103120596 A	29 May 2013
		US 2007282333 A1	06 December 2007
		CN 103120596 B	20 January 2016
		EP 2029034 A2	04 March 2009
		US 2015245849 A1	03 September 2015
		ES 2430330 T3	20 November 2013
		JP 2013046866 A	07 March 2013
		US 8366727 B2	05 February 2013
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		US 2007282332 A1	06 December 2007
		EP 2474275 A2	11 July 2012
CN 1684635 A	19 October 2005	EP 1562495 B1	04 November 2009
		DE 60329933 D1	17 December 2009
		AT 447371 T	15 November 2009
		WO 2004028349 A2	08 April 2004
		US 2004127926 A1	01 July 2004
		AU 2003299086 B2	07 August 2008
		EP 1562495 A4	20 February 2008
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		CA 2499358 C	02 August 2011
		EP 1562495 A2	17 August 2005
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		WO 2004028349 A9	10 June 2004
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		CA 2499358 A1	08 April 2004
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WO 9816157 A1	23 April 1998	AU 726693 B2	16 November 2000

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2017/090329

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
		AU 4756597 A	11 May 1998
		CA 2268977 A1	23 April 1998
		EP 0932365 A1	04 August 1999
		JP 2002500523 A	08 January 2002
US 2002124617 A1	12 September 2002	WO 02070158 A1	12 September 2002
		US 6647755 B2	18 November 2003
		US 2004031308 A1	19 February 2004
CN 104027156 A	10 September 2014	None	

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CN 200480036431 **[0004]**
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Non-patent literature cited in the description

- **LIN GUOQING ; QU ZHE.** Working Principles and Clinical Applications of Ultrasonic Scalpels. *Chinese Medical Equipment Journal,* 2008 **[0002]**
- **ZHOU HONGSHENG ; XU XIAOFANG et al.** Optimized Design of Ultrasonic Scalpels. *Technical Acoustics,* February 2012 **[0002]**

专利名称(译)	超声波手术刀的波导		
公开(公告)号	EP3482702A4	公开(公告)日	2020-02-26
申请号	EP2017826878	申请日	2017-06-27
[标]申请(专利权)人(译)	上海逸思医疗科技有限公司 逸思(苏州)医疗科技有限公司		
申请(专利权)人(译)	上海伊思MEDICAL TECHNOLOGY CO.，LTD.		
当前申请(专利权)人(译)	上海伊思MEDICAL TECHNOLOGY CO.，LTD.		
[标]发明人	LI ZHIDONG LIU RUIXUAN ZHANG YU NIE HONGLIN SHI XIUFENG		
发明人	LI, ZHIDONG LIU, RUIXUAN ZHANG, YU NIE, HONGLIN SHI, XIUFENG		
IPC分类号	A61B17/3211		
CPC分类号	A61B17/320068 A61B17/3211 A61B2017/320072 A61B2017/22018 A61B2017/320089 A61B2017/320082		
优先权	201610542545.4 2016-07-11 CN		
其他公开文献	EP3482702A1		
外部链接	Espacenet		

摘要(译)

具有相对理想的振幅和频率的超声手术刀的波导棒包括近端增益结构，远端增益结构，中间结构和频率调节结构。 近端增益结构和中间结构通过近端侧增益台阶在波导杆的纵向振动的波腹附近的位置处连接。 远端增益结构和中间结构通过远端侧增益台阶在波导棒的纵向振动的波腹附近的位置处连接。 中间结构包括N个（N> 0，并且N是整数）增益保持结构，该增益保持结构通过中间增益步骤在波导棒的纵向振动的波腹附近的位置处端对端地连接。 X（X> 0，并且X是整数）频率调整结构存在于增益保持结构上。 波导杆提供了具有相对较大的叶片幅度的超声手术刀，并且还使超声手术刀能够以稳定且合适的振动频率工作，从而超声手术刀可以有效地切割人体组织。