(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 April 2012 (26.04.2012)

PCT

(10) International Publication Number
WO 2012/053799 A1

(51) International Patent Classification:
G01N 27/62 (2006.01) *H05H 13/00* (2006.01)
H01L 21/265 (2006.01)

(21) International Application Number:
PCT/KR2011/007740

(22) International Filing Date:
18 October 2011 (18.10.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10-2010-0101270 18 October 2010 (18.10.2010) KR

(71) Applicant *(for all designated States except US)*: **KOREA BASIC SCIENCE INSTITUTE** [KR/KR]; 52, Eoeun-dong, Yusung-gu, Daejeon, 305-333 (KR).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **CHOI, Myoung Choul** [KR/KR]; #103-105, Woolim 1-cha Apt., Gak-ri, Ochang-eup, Cheongwon-gun, Chungcheongbuk-do, 363-782 (KR). **KIM, Hyun Sik** [KR/KR]; #14-404, Korea Basic Science Institute Gyosu Apt., Gajeong-dong, Yuseong-gu, Daejeon, 305-350 (KR). **KIM, Seung Yong** [KR/KR]; #610-201, Banseokmaeul 6 danji Apt., Banseok-dong, Yuseong-gu, Daejeon, 305-750 (KR).

(74) Agent: **KIM, Sun-Young**; Korea Coal Center, 10th Floor, 80-6, Susong-Dong, Chongro-Ku, Seoul, 110-727 (KR).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

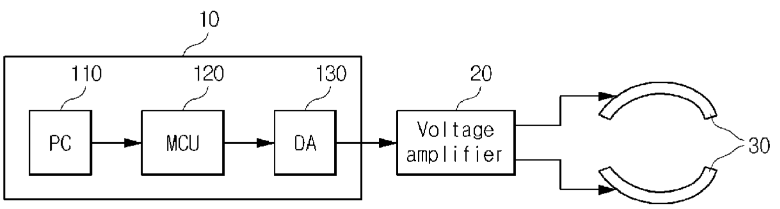
Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) **Title**: FOURIER TRANSFORM ION CYCLOTRON RESONANCE MASS SPECTROMETER USING ULTRA-WIDE-BAND RF AMPLIFIER AND METHOD FOR IMPROVING SIGNAL OF FOURIER TRANSFORM ION CYCLOTRON RESONANCE MASS SPECTROMETER

[Fig. 1]



(57) **Abstract**: A Fourier transform ion cyclotron resonance mass spectrometer (FT-ICR MS) may include: a signal generator generating a sinusoidal, first voltage signal having a DC offset; a voltage amplifier receiving the first voltage signal from the signal generator and generating a second voltage signal by amplifying the first voltage signal; and an ion cyclotron resonance (ICR) trap receiving the second voltage signal and generating an ion cyclotron motion centered on the position determined by the DC offset.

WO 2012/053799 A1

Description

Title of Invention: FOURIER TRANSFORM ION CYCLOTRON RESONANCE MASS SPECTROMETER USING ULTRA-WIDEBAND RF AMPLIFIER AND METHOD FOR IMPROVING SIGNAL OF FOURIER TRANSFORM ION CYCLOTRON RESONANCE MASS SPECTROMETER

Technical Field

[1] Embodiments relate to a novel Fourier transform ion cyclotron resonance mass spectrometer (FT-ICR MS) using an ultra-wideband RF amplifier and a method for improving signal of an FT-ICR MS using the same.

Background Art

[2] A Fourier transform ion cyclotron resonance mass spectrometer (FT-ICR MS) is an apparatus for elucidating the structure of a molecule by measuring the mass of molecular ion and fragment ions. FT-ICR MS has become a basic standard in the high-resolution wideband mass spectrometry. Typically, an FT-ICR MS consists of a cylindrical trap electrode, an activation electrode, a measurement electrode, etc. as well as an RF amplifier for exciting ions so as to increase the cyclotron rotation radius of ions in an ion cyclotron resonance (ICR) trap in order to measure the mass of ions based on the signals induced to the measurement electrode.

[3] The ions in the ICR trap exhibit cyclotron motions such as cyclotron rotation, magnetron rotation and axial trapping oscillation. The frequency of cyclotron rotation is different depending on the mass of ion and the magnitude of magnetic field. When an electric field (high-voltage RF signal) applied perpendicularly to a magnetic field has a characteristic frequency determined by the ion mass and the magnetic field, the ion absorbs the energy and, thus, its rotation radius increases. The resonance frequency is converted to the ion mass. The motion of the ions is due to the Lorentz force, which is exerted to the charged ions moving in a static magnetic field. The magnetron rotation is induced by the radial electric field gradient formed by the electrostatic trapping voltage of the ICR trap. The translational motion of the ion due to the magnetron motion causes ion loss. Also, the ions oscillate linearly along the axial direction of the magnetic field with the trapping oscillation frequency.

[4] As such, the FT-ICR MS is capable of detecting the ion mass by measuring the frequency of the cyclotron motion of the ion in the ICR trap. Therefore, the frequency band of an RF signal generating the cyclotron motion of ion is directly related to the detectable ion mass range. With the conventional high-frequency devices (e.g., FET),

only limited measurement was possible because the frequency band was relatively narrow. In addition, if the center of the cyclotron motion of the ion falls outside the range suitable for measurement, e.g. far away from the center of the ICR trap, ion loss may be triggered by the magnetron motion, resulting in decreased signal intensity. Also, the increased ion loss leads to deteriorated resolution because of decreased overall measurement time.

Disclosure of Invention

Technical Problem

[5] According to an aspect of the invention, a Fourier transform ion cyclotron resonance mass spectrometer (FT-ICR MS) is configured using an ultra-wideband voltage amplifier based on an OP amp. As a result, the frequency band of the high-voltage RF signal applied to an ion cyclotron resonance (ICR) trap is extended up to the DC range, and, therefore, an ion with a larger mass (i.e. larger molecular weight) may be detected as compared to when the existing RF amplifier is used. Further, since the voltage amplifier has a wide operating frequency band up to DC, DC offset may be added to the high-voltage signal. Accordingly, by applying a DC electric field perpendicular to a magnetic field, the center of the ion cyclotron motion in the ICR trap may be adjusted with the E × B motion of the ion in order to improve the signal of the FT-ICR MS.

Solution to Problem

[6] A Fourier transform ion cyclotron resonance mass spectrometer (FT-ICR MS) according to an embodiment may include: a signal generator generating a sinusoidal, first voltage signal having a DC offset; a voltage amplifier receiving the first voltage signal from the signal generator and generating a second voltage signal by amplifying the first voltage signal; and an ion cyclotron resonance (ICR) trap receiving the second voltage signal and generating an ion cyclotron motion centered on the position determined by the DC offset.

[7] A method for improving signal of an FT-ICR MS according to an embodiment may include: generating a sinusoidal, first voltage signal having a DC offset; generating a second voltage signal by amplifying the first voltage signal; and generating an ion cyclotron motion centered on the position determined by the DC offset by applying the second voltage signal to an ICR trap.

Advantageous Effects of Invention

[8] The Fourier transform ion cyclotron resonance mass spectrometer (FT-ICR MS) using an ultra-wideband RF amplifier and the method for improving the signal of an FT-ICR MS according to the invention allow extension of the frequency range of signal applied to an ion cyclotron resonance (ICR) trap because of the relatively wide operating frequency range of the ultra-wideband amplifier. Since ions with a larger

molecular weight (larger ion mass) resonate at lower frequencies, resulting in cyclotron resonance, higher molecular-weight ions may be detected by extending the frequency of the RF voltage signal applied to the ICR trap to lower frequency ranges.

[9] Further, since the extended frequency range reaches up to the DC range, a DC offset of voltage may be added to the outputted high-voltage RF signal, and, by controlling it, the center position of the ion cyclotron motion in the ICR trap may be adjusted. As a result, the phenomenon of ions falling outside the detection range, resulting in decreased measurement signal intensity or ion loss during the measurement, may be prevented or reduced. Consequently, the sensitivity and/or resolution of the FT-ICR MS may be improved.

[10] In addition, since the voltage amplifier of the FT-ICR MS has a fast operation speed in response to the control wave as compared to that of the existing FT-ICR MS and is capable of actively correcting the ouptut voltage gain according to the inptut frequency, a stable ouptut may be obtained.

Brief Description of Drawings

[11] FIG. 1 is a schematic view of a Fourier transform ion cyclotron resonance mass spectrometer (FT-ICR MS) according to an embodiment.

[12] FIG. 2 is a circuit diagram of a voltage amplifier of an FT-ICR MS according to an embodiment.

[13] FIGS. 3a to 3d show the center position of ion cyclotron motion in an FT-ICR MS according to an embodiment depending on DC offset.

[14] FIG. 4a shows the change of ouptut of a voltage amplifier of an existing FT-ICR MS depending on change in inptut waveform.

[15] FIG. 4b shows the change of ouptut of a voltage amplifier of an FT-ICR MS according to an embodiment depending on change in inptut waveform.

[16] FIG. 5a shows the ouptut voltage of a voltage amplifier of an existing FT-ICR MS depending on change in inptut frequency.

[17] FIG. 5b shows the ouptut voltage of a voltage amplifier of an FT-ICR MS according to an embodiment depending on change in inptut frequency.

Mode for the Invention

[18] Hereinafter, the embodiments of the invention will be described in detail with reference to accompanying drawings.

[19] FIG. 1 is a schematic view of a Fourier transform ion cyclotron resonance mass spectrometer (FT-ICR MS) according to an embodiment.

[20] Referring to FIG. 1, an FT-ICR MS according to an embodiment may comprise a signal generator 10, a voltage amplifier 20 and an ion cyclotron resonance (ICR) trap 30. The signal generator 10 applies power, e.g. trapping voltage, to the ICR trap 30 for

measurement of ion mass. The signal generator 10 may generate a sinusoidal, first voltage signal and transmit it to the voltage amplifier 20. The voltage amplifier 20 may receive the first voltage signal from the signal generator 10, convert the first voltage signal into a second voltage signal by amplifying it, and apply it to the ICR trap 30. As a result, a cyclotron motion of ions may be generated in the ICR trap 30 due to the applied voltage.

[21] In an embodiment, the frequency of the first voltage signal and the second voltage signal may range from that of a direct current (DC) to about 1 MHz. Ions with a larger molecular weight ion (larger ion mass) resonate at lower frequencies, resulting in cyclotron resonance. According to this embodiment, since the frequency of the RF voltage signal applied to the ICR trap 30 is extended greatly to lower frequency ranges, it is possible to detect ions with a larger molecular weight.

[22] In an embodiment, the signal generator 10 may comprise a personal computer (PC) 110, a micro controller unit (MCU) 120 and a digital-analog converter (DA) 130. The MCU 120 may generate an ouptut voltage signal according to the waveform designed by the PC 110, and the DA 130 may generate the first voltage signal by converting the voltage signal into an analog signal. The waveform designed by the PC 110 may have a predetermined DC offset. Thus, the first voltage signal outputted from the DA 130 may be a signal having a DC offset. The center position of the ion cyclotron motion in the ICR trap 30 is determined by the DC offset, which will be described in detail later.

[23] The afore-described configuration of the signal generator 10 is only exemplary, and, in other embodiments, the signal generator may have a different configuration capable of outputting a sinusoidal voltage signal.

[24] The first voltage signal generated by the signal generator 10 may be transmitted to the voltage amplifier 20. FIG. 2 is a circuit diagram of a voltage amplifier of an FT-ICR MS according to an embodiment.

[25] Referring to FIG. 2, the voltage amplifier may comprise an OP amp 200, a variable resistor (VR) and first to third resistors (R_1, R_2, R_3). An inverting input terminal (-IN) of the OP amp 200 is an inptut terminal of the voltage amplifier and may be electrically connected, for example, to the first resistor (R_1) and the variable resistor (VR), and a non-inverting input terminal (+IN) of the OP amp 200 may be grounded. And, an output terminal (OUT) of the OP amp 200 is the output terminal of the voltage amplifier and may be electrically connected, for example, to the third resistor (R_3). Further, power supply terminals (+Vs, -Vs) of the OP amp 200 may be electrically connected to the corresponding power sources (+Vss, -Vss) to receive power for operating the OP amp 200.

[26] The first resistor (R_1) may be electrically connected between the inptut terminal of the voltage amplifier and the variable resistor (VR). And, the variable resistor (VR)

may be electrically connected to the inverting input terminal (-IN) of the OP amp 200. Meanwhile, the second resistor (R_2) may be electrically connected between the inverting input terminal (-IN) of the OP amp 200 and the output terminal (OUT). In the voltage amplifier configured as described above, the amplification factor of voltage is determined depending on the ratio of the sum of the resistance of the first resistor (R_1) and the variable resistor (VR) to the resistance of the second resistor (R_2). Accordingly, a desired ouptut voltage of the voltage amplifier may be attained by adjusting the resistance of the variable resistor (VR).

[27] In an embodiment, the magnitude of the first voltage signal inputted to the voltage amplifier may be from 0 to about 20 Vpp (peak-to-peak voltage). And, the magnitude of the second voltage signal amplified by the voltage amplifier may be between 120 and 900 Vpp. However, the above-described magnitude of the voltage is only exemplary, and the magnitude of the first voltage signal and/or the second voltage signal is not limited thereto. The amplified voltage may be outputted from the voltage amplifier through the third resistor (R_3).

[28] The voltage amplifier may further comprise first to fourth diodes (D_1, D_2, D_3, D_4) electrically connected between the inverting input terminal (-IN) of the OP amp 200 and the ground. The first diode (D_1) and the second diode (D_2) may be arranged in the same direction. That is to say, a cathode of the first diode (D_1) may be electrically connected to an anode of the second diode (D_2). Likewise, the third diode (D_3) and the fourth diode (D_4) may be arranged in the same direction. The arrangement direction of the first and second diodes (D_1, D_2) may be different from that of the third and fourth diodes (D_3, D_4). The first to fourth diodes (D_1, D_2, D_3, D_4) arranged as such may prevent an overvoltage inptut to the OP amp 200.

[29] Referring again to FIG. 1, the components of the signal generator 10 and the voltage amplifier 20 are depicted as separate blocks. However, they are distinguished only functionally and may not necessarily be separated physically. In an embodiment, one or more component of the signal generator 10 and/or the voltage amplifier 20 may be integrated as a single device. For instance, the MCU 120 and the DA 130 of the signal generator 10 and the voltage amplifier 20 may be integrated as a single device, and the integrated device may be electrically connected to the PC 110. However, this is only an example, and those skilled in the art will readily understand that other modifications in design not described in the specification are also possible.

[30] As described above, the first voltage signal having the DC offset may be amplified by the voltage amplifier 20, and the amplified signal may be outputted from the voltage amplifier 20 as the second voltage signal and applied to the ICR trap 30. The ICR trap 30 may generate the cyclotron motion of ion using the second voltage signal applied to the voltage amplifier 20 as trapping voltage. The center position of the ion

cyclotron motion generated in the ICR trap 30 may be adjusted by the DC offset of the second voltage signal.

[31] FIGS. 3a to 3d schematically show the center position of the ion cyclotron motion in the FT-ICR MS according to an embodiment depending on the DC offset. FIGS. 3a to 3d show the path of ion cyclotron motion in the ICR trap when the DC offset of the voltage amplifier is about 0 V, about -10 V, about -30 V and about -50 V, respectively. As seen from the figures, the position of ions in the ICR trap moves rightward as the magnitude of the DC offset decreases. By appropriately adjusting the magnitude of the DC offset, the position of the ions in the ICR trap may be adjusted to one suitable for mass measurement (e.g., near the center of the ICR trap).

[32] Accordingly, when the FT-ICR MS according to the embodiment is used, the phenomenon of the center position of the cyclotron motion of ions falling outside the appropriate detection range, e.g., away from the center of the ICR trap, which results in decreased measurement signal intensity or ion loss during the measurement, may be prevented or reduced, while ensuring a wide detection range. Consequently, the sensitivity and/or resolution of the FT-ICR MS may be improved.

[33] FIGS. 4 and 5 are graphs to showing additional advantages provided by the voltage amplifier of the FT-ICR MS according to an embodiment of the invention.

[34] FIG. 4a shows the change of an ouptut voltage 420 (V) of a voltage amplifier of a conventional FT-ICR MS with time (sec) depending on change of a control signal 410. The control signal corresponds to the first voltage signal inputted from the signal generator to the voltage amplifier. As seen in the figure, there is a time delay (t) between the time when a pulse-type control signal 410 is changed into a low-level signal and the time when the ouptut 420 of the voltage amplifier actually decreases. That is to say, the voltage amplifier of the existing FT-ICR MS has a relatively low operation speed in response to the control wave.

[35] FIG. 4b shows the change of an ouptut voltage 440 (V) of a voltage amplifier of an FT-ICR MS according to an embodiment with time (sec) depending on change of a control signal 430. As seen in the figure, as the control signal 410 is changed from a high-level state to a low-level state, the ouptut 440 of the voltage amplifier decreases substantially simultaneously. That is to say, the FT-ICR MS according to the embodiment has a relatively fast operation speed in response to the control wave.

[36] FIG. 5a shows an ouptut voltage 510 of a voltage amplifier of a conventional FT-ICR MS depending on change in inptut frequency. The inptut frequency corresponds to the frequency of the first voltage signal inputted from the signal generator to the voltage amplifier. In the example shown in FIG. 5a, the voltage of the first voltage signal is about 0.1 V. With the voltage amplifier of the conventioanl FT-ICR MS, it is impossible to obtain a stable output when the inptut frequency is below about 10 kHz. In

addition, as the inptut frequency changes, the ouptut voltage 510 changes greatly, resulting in change of ouptut power from about 5 W to about 13 W. As a result, the ouptut voltage is unstable. That is to say, when the ouptut power is about 8 W, the voltage decreases by about 20% with respect to the maximum, and when the ouptut power is about 5 W, the voltage decreases by about 38% with respect to the maximum.

[37] FIG. 5b shows an ouptut voltage of a voltage amplifier of an FT-ICR MS according to an embodiment depending on change in inptut frequency. The three graphs 520, 530, 540 in FIG. 5b are the ouptut voltage of the voltage amplifier when the voltage of the first voltage signal inputted to the voltage amplifier is about 400 V, about 300 V and about 200 V, respectively. As seen from the figure, the ouptut voltage of each graph 520, 530, 540 is maintained constant in most of the inptut frequency ranges. It can be seen that a stable ouptut voltage is attained even near the DC range with the inptut frequency being about 1000 kHz.

[38] Those skilled in the art will appreciate that the conceptions and specific embodiments disclosed in the foregoing description may be readily utilized as a basis for modifying or designing other embodiments for carrying out the same purposes of the present disclosure. Those skilled in the art will also appreciate that such equivalent embodiments do not depart from the spirit and scope of the disclosure as set forth in the appended claims.

Industrial Applicability

[39] Embodiments relate to a novel Fourier transform ion cyclotron resonance mass spectrometer (FT-ICR MS) using an ultra-wideband RF amplifier and a method for improving signal of an FT-ICR MS using the same.

Claims

[Claim 1] A Fourier transform ion cyclotron resonance mass spectrometer comprising:
a signal generator generating a sinusoidal, first voltage signal having a DC offset;
a voltage amplifier receiving the first voltage signal from the signal generator and generating a second voltage signal by amplifying the first voltage signal; and
an ion cyclotron resonance (ICR) trap receiving the second voltage signal and generating an ion cyclotron motion centered on the position determined by the DC offset.

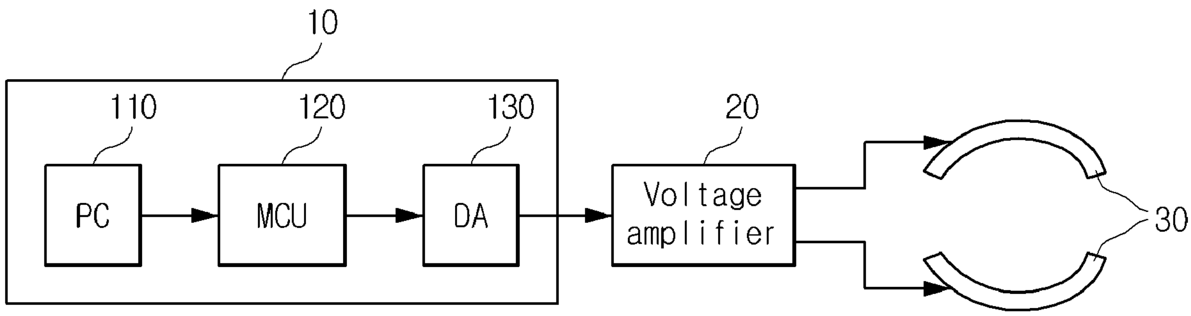
[Claim 2] The Fourier transform ion cyclotron resonance mass spectrometer according to claim 1, wherein the DC offset is determined such that the center position of the ion cyclotron motion in the ICR trap is in proximity to the center of the ICR trap.

[Claim 3] The Fourier transform ion cyclotron resonance mass spectrometer according to claim 1, wherein the voltage amplifier comprises:
an OP amp;
a variable resistor electrically connected to an inverting input terminal of the OP amp;
a first resistor electrically connected between the variable resistor and the signal generator; and
a second resistor electrically connected between the inverting input terminal of the OP amp and an output terminal of the OP amp.

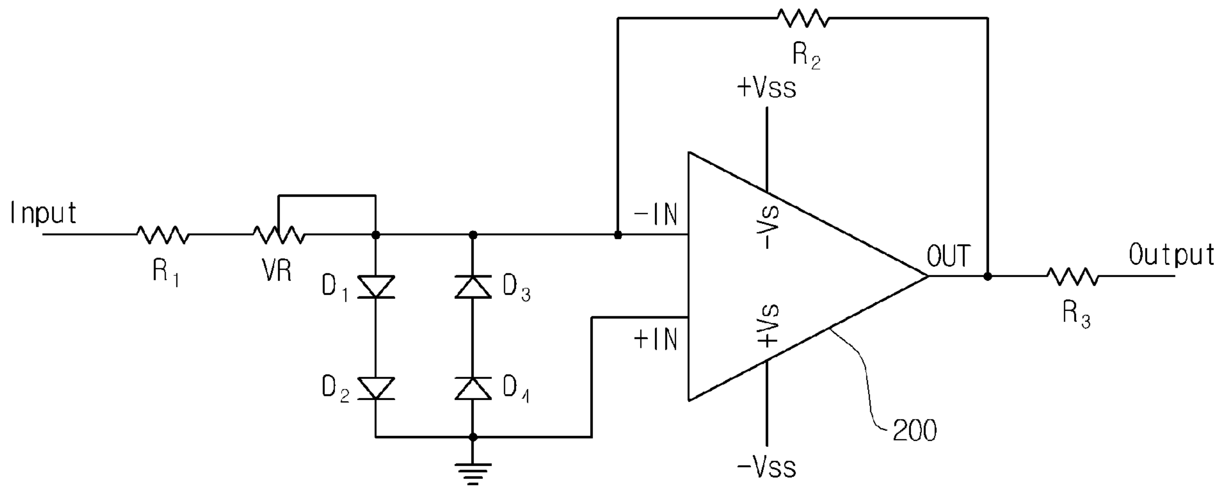
[Claim 4] A method for improving the signal of a Fourier transform ion cyclotron resonance mass spectrometer, the method comprising:
generating a sinusoidal, first voltage signal having a DC offset;
generating a second voltage signal by amplifying the first voltage signal; and
generating an ion cyclotron motion centered on the position determined by the DC offset by applying the second voltage signal to an ion cyclotron resonance trap.

[Claim 5] The method for improving the signal of a Fourier transform ion cyclotron resonance mass spectrometer according to claim 4, wherein the generating the first voltage signal comprises determining the DC offset such that the center position of the ion cyclotron motion in the ICR trap is in proximity to the center of the ICR trap.

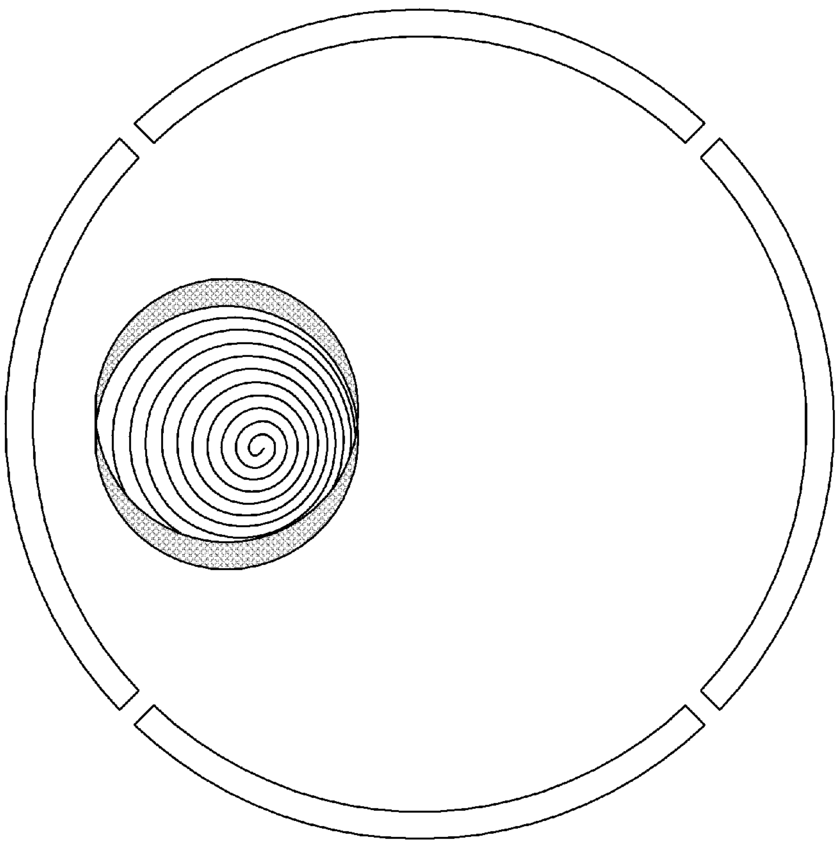
[Fig. 1]



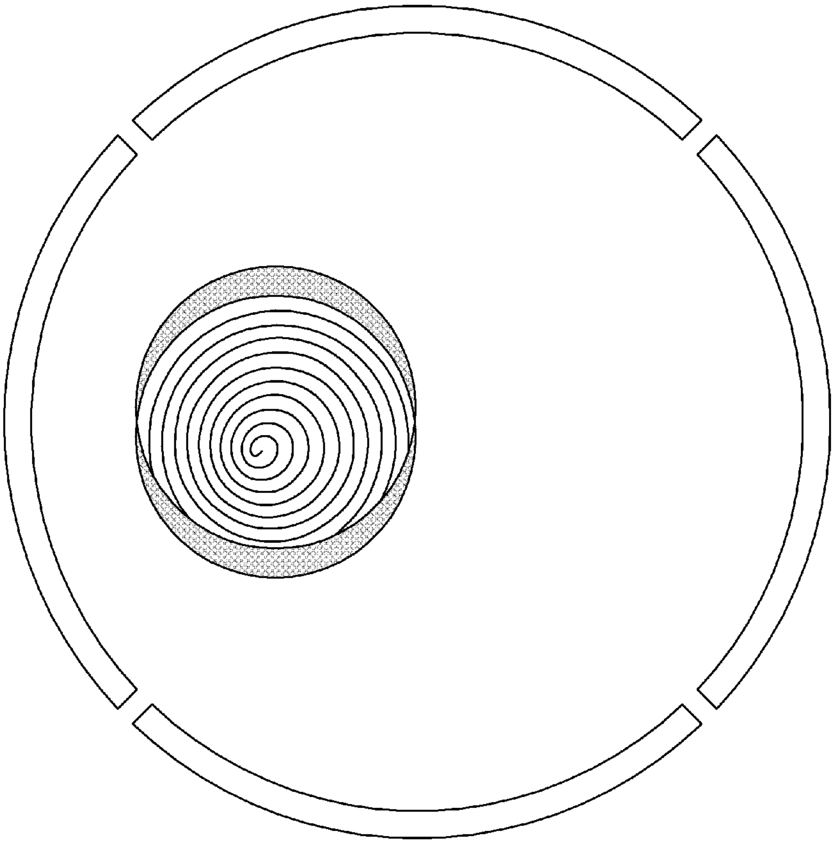
[Fig. 2]



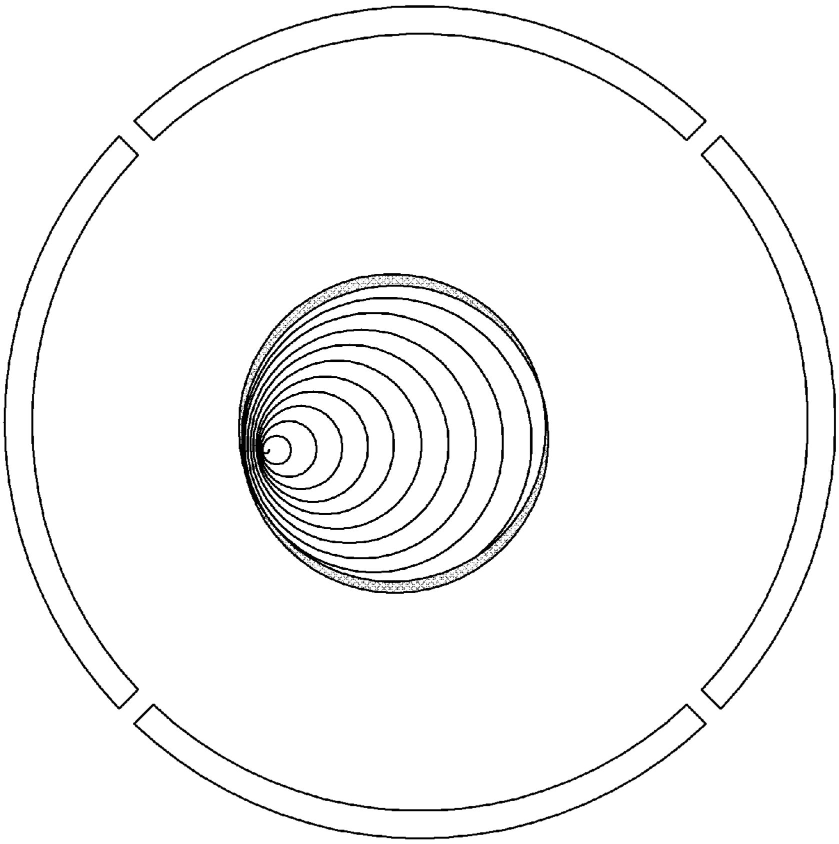
[Fig. 3a]



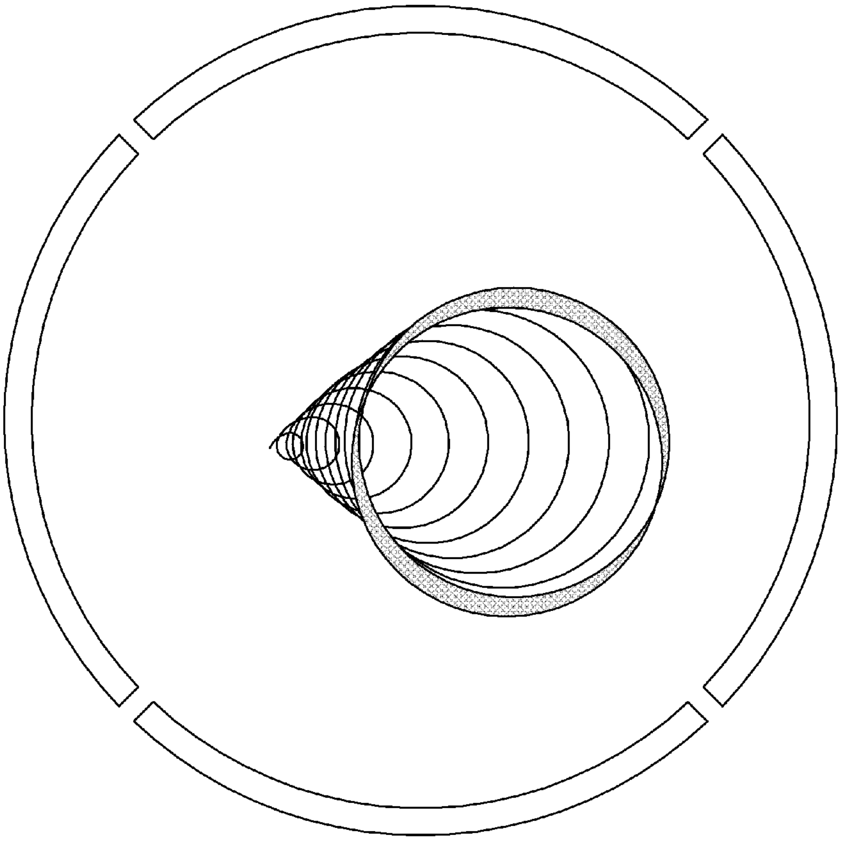
[Fig. 3b]



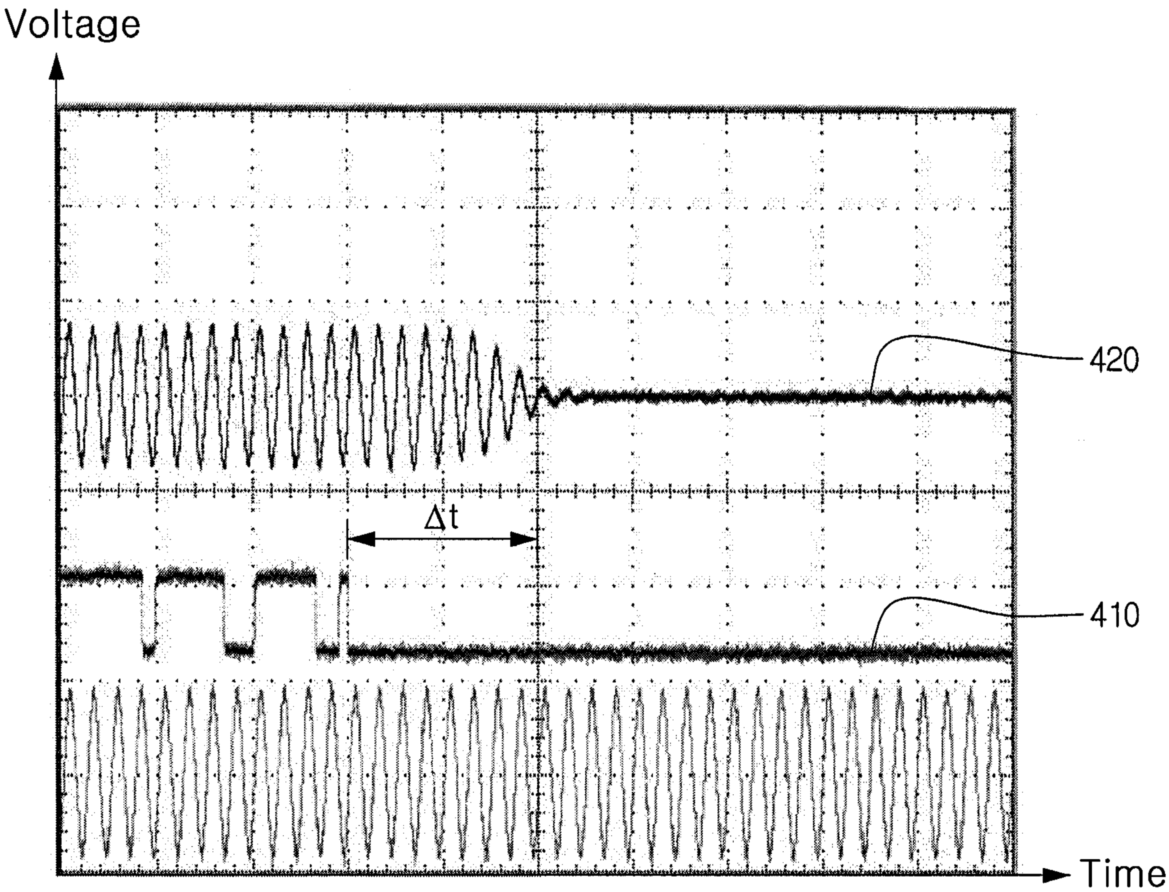
[Fig. 3c]



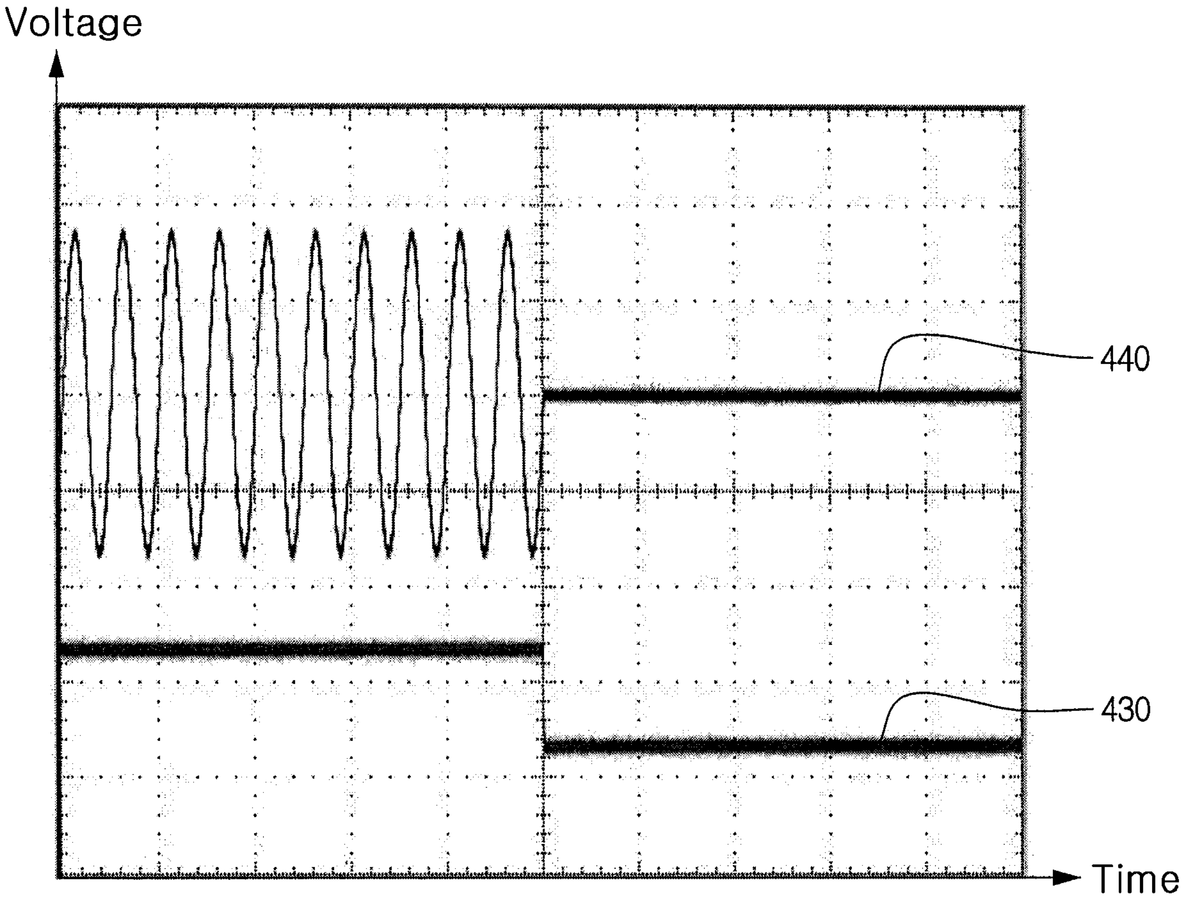
[Fig. 3d]



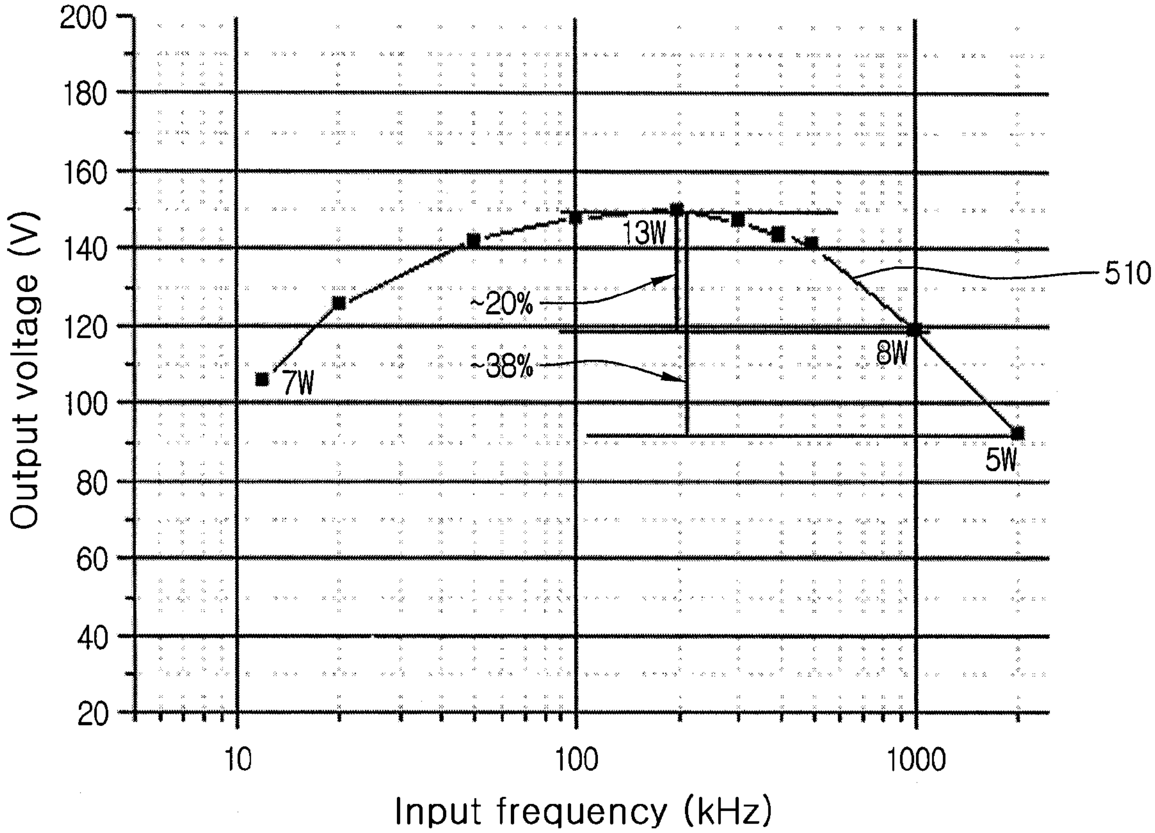
[Fig. 4a]



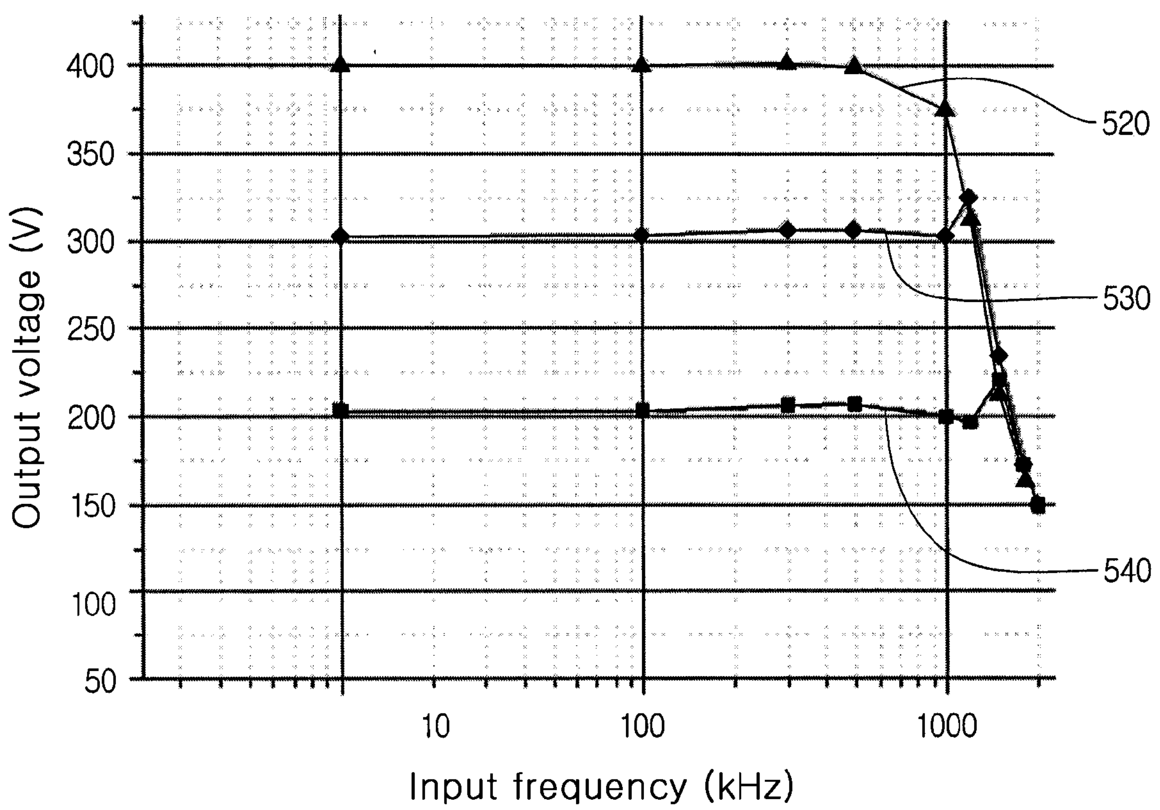
[Fig. 4b]


Voltage
440
430
Time

[Fig. 5a]


200
180
160
140
120
100
80
60
40
20
Output voltage (V)
10
100
1000
Input frequency (kHz)
13W
~20%
~38%
7W
8W
5W
510

[Fig. 5b]



400
350
300
250
200
150
100
50
Output voltage (V)
10
100
1000
Input frequency (kHz)
520
530
540

INTERNATIONAL SEARCH REPORT	International application No. **PCT/KR2011/007740**

A. CLASSIFICATION OF SUBJECT MATTER

G01N 27/62(2006.01)i, H01L 21/265(2006.01)i, H05H 13/00(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)

G01N 27/62; G01N 24/14; H01J 49/42; H01L 21/265

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords:FT-ICR MS,amplifier

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2008-503864 A (Thermo Finnigan LLC) 07 February 2008 See [0048],[0054] and figure 4	1-5
A	KR 10-2008-0093585 A (KOREA BASIC SCIENCE INSTITUTE) 22 October 2008 See abstract and figure 1	1-5
A	KR 10-0790532 B1 (KOREA BASIC SCIENCE INSTITUTE) 02 January 2008 See claim1 and figure 1	1-5
A	KR 10-2009-0073524 A (KOREA BASIC SCIENCE INSTITUTE) 03 July 2009 See abstract amd figure 2	1-5

☐ 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 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
12 MARCH 2012 (12.03.2012)	**13 MARCH 2012 (13.03.2012)**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office Government Complex-Daejeon, 189 Cheongsa-ro, Seo-gu, Daejeon 302-701, Republic of Korea	YEO, Kyeong Sook
Facsimile No. 82-42-472-7140	Telephone No. 82-42-481-5612

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2008-503864 A	07.02.2008	CA 2572553 A1	29.12.2005
		CA 2572553 C	09.08.2011
		CN 101002296 A	18.07.2007
		EP 1774564 A2	18.04.2007
		GB 0413852 D0	21.07.2004
		GB 2415541 A	28.12.2005
		GB 2415541 B	23.09.2009
		JP 04-553937 B2	23.07.2010
		JP 2008-503864 T	07.02.2008
		JP 4553937 B2	29.09.2010
		US 2008-0048112 A1	28.02.2008
		US 2009-0127456 A1	21.05.2009
		US 2011-0315873 A1	29.12.2011
		US 7498571 B2	03.03.2009
		US 8030613 B2	04.10.2011
		WO 2005-124821 A2	29.12.2005
		WO 2005-124821 A3	07.12.2006
		WO 2005-124821 A3	29.12.2005
KR 10-2008-0093585 A	22.10.2008	WO 2008-126976 A1	23.10.2008
KR 10-0790532 B1	02.01.2008	JP 04-460565 B2	19.02.2010
		JP 2008-117738 A	22.05.2008
		JP 4460565 B2	12.05.2010
		US 2008-0099672 A1	01.05.2008
		US 7696476 B2	13.04.2010
KR 10-2009-0073524 A	03.07.2009	US 2009-0166533 A1	02.07.2009