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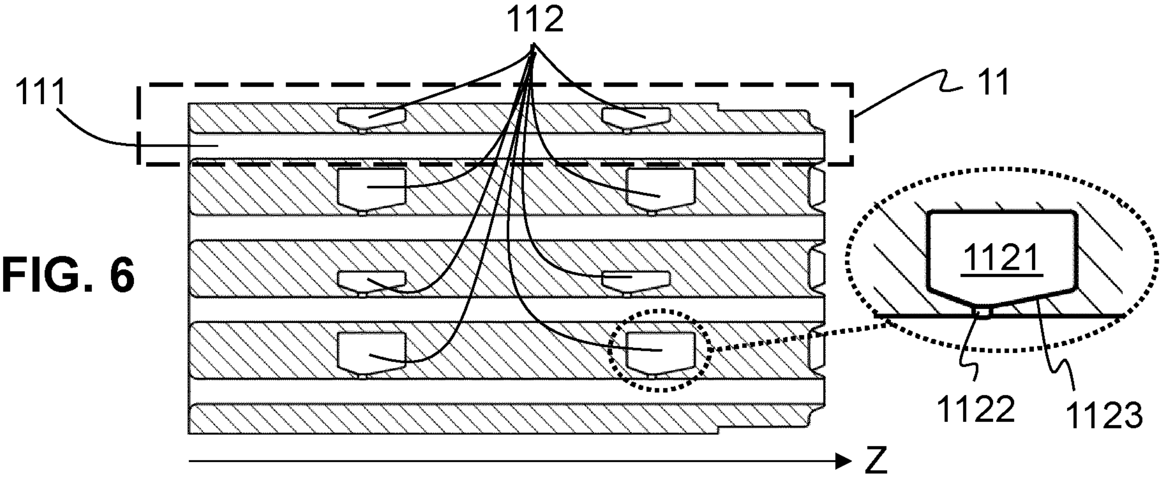
(54) **INJECTOR DEVICE FOR AN ENGINE**


(57) An injector device (10) comprises a plurality of fluid channel assemblies (11), each fluid channel assembly (11) exhibiting an assembly eigenfrequency $f_a$, wherein at least two different types of fluid channel assemblies (11) occur among the plurality of fluid channel assemblies (11). The at least two different types of fluid channel assemblies (11) differ from each other with respect to their assembly eigenfrequency $f_a$. Each fluid channel assembly (11) comprises a fluid channel (111) for guiding a mixture comprising an oxidizing agent and a fuel towards a combustion chamber of an engine device, the fluid channel (111) exhibiting a channel eigenfrequency $f_c$. At least one of the fluid channel assemblies (11) comprises at least one detuning cavity (112) being fluidically connected to its fluid channel (111), the at least one detuning cavity exhibiting a detuning cavity eigenfrequency $f_d$ that differs from the channel eigenfrequency $f_c$ of the fluid channel (111).


**FIG. 6**

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## Description

### TECHNICAL FIELD

**[0001]** The present invention relates to an injector device for an engine device, an engine device comprising said injector device, and a method of manufacturing said injector device.

### PRIOR ART

**[0002]** In combustors of turbines, rocket engines, and furnaces, fuel and oxidizer are typically mixed in an injector device, often called a burner, and then led to a combustion chamber arranged downstream of the injector device. The stability of the combustion process is affected by multiple factors, among others the acoustics of the injector device and the combustion chamber. Instabilities arising from a thermoacoustic feedback loop can impinge on a safe and clean operation of the combustor and the engine. These thermoacoustic instabilities may be mitigated using active or passive control strategies.

**[0003]** US 2022106928 A1 discloses an injector device for an engine device for introducing a fuel and an oxidizing agent into a combustion chamber of an engine device. The injector device defines a longitudinal axis and comprises a first injection element, which is configured in the form of a first fluid channel for fluidically connecting a first collection space for the fluidic oxidizing agent and the combustion chamber, and a second injection element, which is configured in the form of a second fluid channel for fluidically connecting a second collection space for the fluidic fuel and the combustion chamber. At least one first resonator element is associated with the first injection element and/or at least one second resonator element is associated with the second injection element. The first resonator element is adapted to an eigenfrequency of the associated first injection element and/or the second resonator element is adapted to an eigenfrequency of the associated second injection element. The first resonator element and the second resonator element form damping elements in order to dampen flame oscillations in the combustion chamber with the acoustic eigenfrequencies of the injection elements.

**[0004]** However, in order to precisely hit the eigenfrequency, several parameters need to be taken into account. US 2022106928 A1 discloses that to make the geometrical design of the resonator element independent of the sound speed and thus also independent of the respective fluid, flushing channels are needed that connect the resonator element to the respective collection space so that the sound speed in the injection element is the same as in the resonator element.

**[0005]** Such flushing channels however lead to a more complex structure of the injector device, which is also more difficult to manufacture.

### SUMMARY OF THE INVENTION

**[0006]** In a first aspect, it is thus an object of the present invention to provide an injector device which enables a suppression of thermoacoustic instabilities while being simple to design and manufacture.

**[0007]** This object is solved by an injector device according to claim 1. Further embodiments of the invention are laid down in the dependent claims.

**[0008]** An injector device for an engine device is thus provided, the injector device comprising:

> a plurality of fluid channel assemblies, each fluid channel assembly forming an assembly resonator exhibiting an assembly eigenfrequency,
> wherein at least two different types of fluid channel assemblies occur among the plurality of fluid channel assemblies, the at least two different types of fluid channel assemblies differing from each other with respect to their assembly eigenfrequency $f_a$,
> wherein each fluid channel assembly comprises:
> a fluid channel for guiding an oxidizing agent, a fuel, or a mixture comprising an oxidizing agent and a fuel, towards a combustion chamber of the engine device, the fluid channel forming a channel resonator exhibiting a channel eigenfrequency $f_c$, and
> wherein at least one of the fluid channel assemblies comprises:
>
> > at least one detuning cavity being fluidically connected to its fluid channel, the at least one detuning cavity forming a cavity resonator exhibiting a detuning cavity eigenfrequency $f_d$,
> > wherein the detuning cavity eigenfrequency $f_d$ differs from the channel eigenfrequency $f_c$ of the fluid channel to which it is connected.

**[0009]** By having at least two types of fluid channel assemblies that differ from each other with respect to their assembly eigenfrequency $f_a$, resonances are distributed over a larger frequency range and thus acoustic instabilities are mitigated compared to a case in which all fluid channel assemblies have the same assembly eigenfrequency $f_a$.

**[0010]** When designing the injector device, making sure that the detuning cavity eigenfrequency $f_d$ differs from the channel eigenfrequency $f_c$ of the fluid channel to which it is connected represents a significantly simpler task than having to precisely match the channel eigenfrequency $f_c$. Non-matching eigenfrequencies imply that a larger range of parameter values for different design parameters, in particular geometrical dimensions, may be used, which furthermore lowers the demands regarding manufacturing precision. This in turn simplifies the manufacturing process.

**[0011]** The more different assembly eigenfrequencies $f_a$ occur within the injector device, the more "polyphonic" the injector device becomes, i.e. the better acoustic resonances potentially leading to instabilities may be suppressed. Preferably, the injector device comprises a number N of fluid channel assemblies and a number M of different types of fluid channel assemblies differing from each other with respect to their assembly eigenfrequency occurs among the N fluid channel assemblies, the ratio M/N being in the range of 0.5-1.

**[0012]** Preferably, the detuning cavity eigenfrequencies $f_d$ are larger than the fluid channel eigenfrequencies $f_c$, in particular, the detuning cavity eigenfrequencies $f_d$ may be more than 1.5 times larger than the fluid channel eigenfrequencies $f_c$.

**[0013]** Preferably, the fluid channels have a uniform cross-section, preferably circular, and a uniform channel length, i.e. all the fluid channels have the same channel length. This enables nominally identical flow conditions in all the fluid channels, which provides a robust and homogeneous combustion process.

**[0014]** In a particularly simple embodiment, the fluid channels may be straight cylindrical channels.

**[0015]** Preferably the fluid channels extend all the way from a first end of the injector device to a second end of the injector device, wherein the second end is configured to be oriented towards a combustion chamber of an engine when the injector device is used in said engine. The fluid channels may be open at the first end and configured to draw the oxidizing agent, e.g. air, into the injector device from the first end of the injector device.

**[0016]** In preferred embodiments, the difference in assembly eigenfrequency between the different types of fluid channel assemblies is at least partially caused by the detuning cavities of the different types having different detuning cavity volumes.

**[0017]** The detuning cavity volume is a simple design parameter that may be used to predicably and deliberately set the detuning cavity eigenfrequency $f_d$ or each detuning cavity to a desired value.

**[0018]** Alternatively or additionally, the difference in assembly eigenfrequency $f_a$ between the different types of fluid channel assemblies may be at least partially caused by the different types having a different number of detuning cavities being fluidically connected to the respective fluid channel.

**[0019]** Varying the number of detuning cavities per fluid channel provides another simple means to set the assembly eigenfrequency $f_a$ in a predictable and deliberate manner, and in particular may provide an alternative or additional degree of freedom in cases where a range over which the cavity volume of the individual detuning cavities can be varied may be limited by space constraints and/or manufacturing constraints.

**[0020]** In some embodiments, each fluid channel may comprise a mixing region for mixing the oxidizing agent, e.g. air, or oxygen, or other gas mixtures containing oxygen, with the fuel, e.g. hydrogen, natural gas, ammonia or blends of different fuels and inert gases. In such a case, the at least one detuning cavity is preferably arranged downstream of the mixing region. If the at least one detuning cavity is arranged downstream of the mixing region, the fluidic exchange between the fluid channel and the at least one detuning cavity occurs with a homogeneous mixture, i.e. the mixture that is effectively being guided towards the combustion chamber, and thus the at least one detuning cavity has a directly predictable impact on the acoustic properties, in particular on the fluid channel assembly eigenfrequency $f_a$, of the fluid channel assembly.

**[0021]** Each fluid channel may be delimited by a channel wall, the channel wall comprising a fuel injection hole for allowing the fuel to enter the mixing region, wherein the fuel injection hole is preferably arranged upstream of the at least one detuning cavity.

**[0022]** The fluid channels may extend in parallel to each other, thereby defining a common flow direction. In such a case, the injection holes of each fluid channel are preferably arranged in a common injection plane with respect to the common flow direction, which enables a uniform mixing homogeneity across all the fluid channel assemblies and thus enables a reduction of the emission of pollutants.

**[0023]** The detuning cavities may be arranged at the same position or at different positions relative to each other with respect to the common flow direction.

**[0024]** In some embodiments, the injector device may comprise a mixing section, which is preferably arranged at the first end of the injector device. The mixing section may comprise a fuel lance configured to guide fuel into the injector device. The injector device may further comprise a fuel distribution space, which is fluidically connected to the fluid channels, preferably via the injection holes mentioned above, and which may surround the fluid channels. The fuel lance may directly open into said fuel distribution space.

**[0025]** Each fluid channel may be spaced apart from the other fluid channels in a plane perpendicular to the flow direction by a gap which is at least as large as a cross section of the respective fluid channel.

**[0026]** The fluid channels may be arranged equidistantly from each other so as to form a rectangular grid or matrix structure.

**[0027]** In order to enable a compact design, at least one detuning cavity may be arranged in-between two fluid channels.

**[0028]** The injector device may comprise a base body and the fluid channels may be through holes formed in said base body, the through holes preferably having a circular cross section. The through holes may extend from the first end of the injector device to the second end of the injector device that is configured to be oriented towards the combustion chamber.

**[0029]** At least one of the detuning cavities may be a quarter-wave resonator with a circular cross section that is preferably smaller than a cross section of the fluid channel to which it is fluidically connected.

**[0030]** In the present context, the term "quarter-wave resonator" refers to a tube-shaped cavity which has one closed tube end and one open tube end, i.e. wherein an acoustic velocity node occurs at the closed tube end and an acoustic velocity anti-node occurs at the open tube end, the open tube end opening into the fluid channel.

**[0031]** Alternatively or additionally, at least one of the detuning cavities may be a Helmholtz-resonator with a main cavity and a neck through which the detuning cavity is fluidically connected to the fluid channel.

**[0032]** In the present context, the term Helmholtz-resonator refers to a cavity resonator whose eigenfrequency $f_d$ is given by the following expression:

$$f_d = \frac{c}{2\pi}\sqrt{\frac{S_0}{V_0(L + 2\Delta L)}}$$

wherein $S_0$ corresponds to the cross section of the neck, L corresponds to the length of the neck, $V_0$ is the volume of the main cavity and the term $2\Delta L$ is an end correction factor.

**[0033]** The injector device is preferably shaped such that it supports itself during the manufacturing process, which may be a 3D-printing process. Preferably, the fluid channels and the detuning cavities may be arranged and/or shaped such that material powder used in the 3D-printing process may be removed afterwards without needing additional removal holes.

**[0034]** To this end, the main cavity of the detuning cavity may have a funnel-shaped wall surrounding the neck to facilitate the removal of loose material powder through the fluid channel.

**[0035]** In a second aspect, the invention provides a method of manufacturing an injector device according to any one of the preceding claims, wherein the injector device is manufactured using a 3D-printing process.

**[0036]** Preferably, the 3D-printing process comprises selective laser melting (SLM) of a powder material, preferably a metal. In particular, the powder material may be stainless steel or a nickel-chromium alloy.

**[0037]** Prior to the 3D-printing process, the method may comprise a design step in which the injector device is numerically designed using computer-aided design (CAD).

**[0038]** In a third aspect, the invention provides an engine device comprising:

an oxidizer collection space for collecting an oxidizing agent;
a fuel reservoir for containing a fuel,
a combustion chamber, and
an injector device as described above, wherein the injector device is arranged to fluidically connect the oxidizer collection space and the fuel reservoir to the combustion chamber.

**[0039]** The oxidizer collection space may be physically delimited, e.g. by walls, or open into free space. The oxidizer collection space may in particular be an open space if the oxidizing agent is environmental air.

BRIEF DESCRIPTION OF THE DRAWINGS

**[0040]** Preferred embodiments of the invention are described in the following with reference to the drawings, which are for the purpose of illustrating the present preferred embodiments of the invention and not for the purpose of limiting the same. In the drawings,

Fig. 1 shows a schematic overview of an engine device comprising an injector device, which may be an injector device according to the embodiments of the present invention shown in Figs. 3-13;
Fig. 2 shows a schematic sectional view of an injector device according to the prior art;
Fig. 3 shows a perspective view of an injector device according to a first embodiment of the present invention;
Fig. 4 shows a side view of the first shown in Fig. 3;
Fig. 5 shows a sectional view of the first embodiment in the sectional plane A-A of Fig. 4;
Fig. 6 shows a sectional view of the first embodiment in the sectional plane B-B of Fig. 5;
Fig. 7 shows a side view of an injector device according to a second embodiment of the present invention with a partial section showing a mixing section of the injector device;
Fig. 8 shows a sectional view of the second embodiment in the sectional plane C-C of Fig. 7;
Fig. 9 shows a sectional view of the second embodiment in the sectional plane A-A of Fig. 7;
Fig. 10 shows a sectional view of the second embodiment in the sectional plane D-D of Fig. 8;
Fig. 11 shows a sectional view of the sectional plane E-E of Fig. 12;
Fig. 12 shows a sectional view of the sectional plane H-H of Fig. 11;
Fig. 13 shows a sectional view of the sectional plane J-J of Fig. 11;
Fig. 14 shows a schematic flow diagram of a manufacturing process according to the second aspect of the present invention, and
Fig. 15 shows an acoustic spectrum device measured for an injector device according to the second embodiment of the present invention shown in Figs. 7-10, and for an injector device that does not have any detuning cavities.

DESCRIPTION OF PREFERRED EMBODIMENTS

**[0041]** Fig. 1 schematically shows an engine device which comprises a combustor 2 that comprises an injector device 10 and a combustion chamber 40 arranged downstream of the injector device 10. An oxidizer collection space 20 is arranged upstream of the injector device

10, which acts as a reservoir for an oxidizing agent O. The oxidizer collection space may be physically delimited, e.g. by walls, or open into free space. The oxidizer collection space may in particular be an open space if the oxidizing agent O is environmental air. In the embodiment of an engine 1 shown in Fig. 1, a compressor 21 is arranged within the oxidizer collection space 20 to compress the oxidizing agent O prior to its entrance into the injector device 10. Furthermore, a fuel reservoir 30 comprising a fuel F is arranged upstream of the injector device 10. Depending on the embodiment, the injector device 10 may be configured to receive both the fuel F and the oxidizing agent O, and to generate a mixture comprising the fuel F and the oxidizing agent O, or may be configured to receive a pre-mixed mixture comprising the fuel F and the oxidizing agent O. The mixture is guided through the injector device 10 into the combustion chamber 40. The mixture is ignited and burns inside the combustion chamber 40, thereby generating flames 41. Hot gases G generated in this process are then directed towards a turbine 50, which may be used to drive the compressor 21 and/or other devices. Exhaust gases EG exiting the turbine 50 may be used e.g. to produce thrust.

**[0042]** Fig. 2 shows a schematic sectional view of an injector device 10 according to the prior art being arranged upstream of a combustor chamber 40. The injector device 10 comprises a plurality of fluid channels 111, into which both the fuel F and the oxidizing agent O are being injected. The fluid channels 111 are arranged in parallel to each other and have the same geometrical dimensions, thus exhibiting resonances with the same channel eigenfrequency $f_c$, which can generate an unwanted thermoacoustic feedback loop in combination with the combustor chamber 40 and thus deteriorate the operation of the engine.

**[0043]** Figs. 3-6 show an injector device 10 according to a first embodiment of the present invention. Fig. 3 shows a perspective view, Fig. 4 shows a side view, Fig. 5 shows a sectional view of the sectional plane A-A of Fig. 4, and Fig. 6 shows a sectional view of the sectional plane B-B marked in Fig. 5 together with an enlarged view of a detuning cavity.

**[0044]** In the embodiment shown in Figs. 3-6, the injector device has a base body 12 with a quadratic cross section. The fluid channels 111 are through holes formed in said base body 12. The injector device 10 comprises sixteen fluid channel assemblies 11 (N=16), wherein eight different types (M=8) occur among the sixteen fluid channel assemblies 11, each type having a different assembly eigenfrequency $f_a$. Each channel assembly 11 comprises a fluid channel 111. The fluid channels 111 extend in parallel to each other along a common flow direction Z and have the same length in Z-direction. They are arranged to form a 4x4-matrix with gaps of equal size between the fluid channels 111. The fluid channels 111 have a circular cross section in a plane perpendicular to the common flow direction, the cross-section being uniform, i.e. having the same size for all fluid channels 111. The gaps between the fluid channels 111 are larger than the cross section of the fluid channels 111. This leaves sufficient space to arrange detuning cavities 112 of various sizes within these gaps, i.e. in-between two fluid channels 111. In this embodiment, some detuning cavities 112 are additionally arranged within an edge zone of the base body 12, i.e. in this case outside the quadratic area defined by the 4x4-matrix of fluid channels 111.

**[0045]** Since the fluid channels 111 in this first embodiment all have the same length and cross section, all fluid channels 111 nominally have the same channel eigenfrequency $f_c$. The difference in assembly eigenfrequency $f_a$ is thus caused by the detuning cavities 112, which are fluidically connected to the individual fluid channels 111, having different detuning cavity volumes.

**[0046]** In the present example, fourteen fluid channel assemblies 11 among the sixteen fluid channel assemblies 11 each comprise two detuning cavities 112 that are fluidically connected to the fluid channel 111 of the respective fluid channel assembly 11. The two detuning cavities 112 connected to the same fluid channel 111 have the same detuning cavity volume, in particular the same geometrical dimensions. However, in a modification of this embodiment, the detuning cavities 112 being connected to the same fluid channel 111 may also have different detuning cavity volumes.

**[0047]** In the sectional view shown in Fig. 5, fourteen detuning cavities 112 are visible. In the sectional view shown in Fig. 6, four channel assemblies 11 are visible, each channel assembly 11 having one fluid channel 111 and two detuning cavities 112 being fluidically connected to each fluid channel 111. The detuning cavities 112 each have a main cavity 1121 and a neck 1122 via which they are fluidically connected to the respective channel. The main cavity has a funnel-shaped wall 1123 surrounding the neck 1122. Such a funnel-shaped wall 1123 is particularly advantageous if the injector device 10 is manufactured using a 3D-printing process based on powder material, since loose powder particles potentially remaining in the main cavities 1121 after the printing process may easily be removed from the main cavities 1121 by shaking the injector device 10 such that the loose powder particles gather at the bottom of the funnel-shaped wall 1123 and thus fall through the neck into the respective fluid channels 111, from where they then may be extracted by tilting the injector device 10 such that the fluid channels 111 are aligned with the direction of gravity.

**[0048]** Four of the detuning cavities 112 visible in Fig. 6 are arranged at the same position with respect to the common flow direction Z, while the other four detuning cavities 112 visible in Fig. 6 are arranged at different position with respect to the common flow direction Z, i.e. with the neck 1122 of the detuning cavities 112 not being arranged in the same sectional plane perpendicular to the common flow direction Z due to geometrical constraints related to how this specific embodiment is meant to be mounted and sealed for testing in a test rig. In a modification of this embodiment, it would however be conceivable for the position of the detuning cavities 113 with respect to the common flow direction Z to be different than in the example shown in Fig. 6.

**[0049]** Figs. 7-10 show an injector device 10 according to a second embodiment of the present invention. This second embodiment comprises all features of the first embodiment described above and thus the description provided above also applies to the second embodiment. Additionally, the injector device 10 according to this second embodiment comprises a mixing section 13 arranged at a first end of the injector device 10, the first end being opposite a second end of the injector device 10, the second end being configured to be connected to the combustion chamber 50 when installed in an engine device as shown in Fig. 1.

**[0050]** Fig. 7 shows a partial section of the injector device 10, where the mixing section 13 is cut open along a central sectional plane D-D. The central sectional plane D-D is marked in Fig. 8, which in turn corresponds to a sectional view of the sectional plane C-C marked in Fig. 7. Fig. 9 shows a sectional view along the sectional place A-A of Fig. 7, and Fig. 10 shows a sectional view of the sectional plane B-B marked in Fig. 9 together with an enlarged view of a fuel injection hole.

**[0051]** The mixing section 13 comprises a fuel lance 131, which partially extends outside the base body 12. The fuel lance 131 opens into a fuel distribution space 132, which corresponds to a hollow space surrounding the fluid channels 111 within the base body 12. The fluid channels 111 extend through the mixing section and each fluid channel 111 has an open end at the first end of the injector device 10. Each fluid channel 111 is delimited by a channel wall 1111. In the embodiment shown in Figs. 7-10, two diametrically opposed injection holes 1112 are arranged in the channel wall 1111 of each fluid channel 111 to enable a fluidic exchange between the fuel distribution space 132 and the fluid channel 111. In a typical use case, a fuel F may be inserted into the fuel distribution space 132 through the fuel lance 131, while an oxidizing agent O is drawn into the fluid channels 111 from their respective open ends located at the first end of the injector device 10. The fuel F then enters the fluid channels 111 via the fuel injection holes 1112 and gets mixed with the oxidizing agent O in a mixing region 1113 of each fluid channel 111, the mixing region 1113 being located around and/or downstream of the injection holes 1112. Preferably, as shown in Fig. 10, the mixing region 1113 is arranged upstream of the detuning cavities 112. Ideally, the injection holes 1112 are much smaller in diameter than the cross section of the fluid channel 111, i.e. preferably 10-15 times smaller, to enable a large flow velocity of the fuel F and to acoustically decouple the fuel distribution space 132 from the fluid channels 111. In a specific example, the fluid channels 111 have an inner diameter of 6 mm and the injection holes 1112 have a diameter of 0.5 mm.

**[0052]** Figs. 11-13 illustrate a variety of different shapes that the detuning cavities 112 may have within an injection device 10 according to the present invention. Fig. 11 is a sectional view of the sectional plane E-E of Fig. 12, while Fig. 12 is a sectional view of the sectional plane H-H of Fig. 11. Fig. 13 is a sectional view of the sectional plane J-J of Fig. 11.

**[0053]** The detuning cavities 112 shown in Fig. 12 have a cuboidal main cavity 1121 and a neck 1122 which connects the main cavity 1121 to the fluid channel 111, thus forming a Helmholtz-type resonator.

**[0054]** The detuning cavities 112 shown in Fig. 13 are examples of quarter-wave resonators which are formed as blind holes within the base body 12. The quarter-wave resonators each have a circular cross section that is smaller than the cross section of the fluid channel 111 to which they are fluidically connected. They each comprise a main section that extends substantially in parallel to the fluid channel 111 to which they are fluidically connected, and a bent neck section that opens into the respective fluid channel 111, wherein the bent neck section has the same cross section as the main section. In the embodiment shown in Fig. 13, the bent neck section is arranged towards the first end of the injection device 10, i.e. towards the input side through which the fuel F and the oxidizing agent O enter the injection device 10 when the latter is in use. However, in other embodiments, the bent neck section may alternatively be arranged towards the second end of the injection device 10.

**[0055]** Any of the shapes shown in Figs. 11-13 may be used in the first embodiment or the second embodiment of the injector device 10 discussed above. As shown in Fig. 12 and Fig. 13, an arbitrary number of detuning cavities 112 may be connected to a single fluid channel 111. It is also conceivable for the detuning cavities 112 to not only have different volumes, but also to be of different shape and/or of different resonator type, i.e. of the Helmholtz-type or the quarter-wave type.

**[0056]** In further embodiments, the number N of fluid channel assemblies 11 may be scaled arbitrarily and the fluid channels 111 do not need to be aligned in a rectangular matrix, but may alternatively be arranged to form concentric circles or any other suitable pattern.

**[0057]** Fig. 14 schematically illustrates a method of manufacturing an injector device according to an embodiment of the present invention. In a first step, the injector device is designed using computer-aided design (CAD). In a second step, the injector device is manufactured using a 3D-printing process, wherein the 3D-printing process comprises selective laser melting (SLM) of a powder material.

**[0058]** Fig. 15 shows an acoustic spectrum measured both for an injector device 10 according to the second embodiment of the present invention shown in Figs. 7-10 (solid line), and for an injector device that does not have any detuning cavities (dashed line), but that is otherwise identical to said second embodiment. To obtain the measured spectra, the injector devices were mounted on a test rig equipped with a combustion chamber arranged downstream of the injector device. A hydrogen (fuel) - air (oxidizing agent) mixture at an equivalence ratio of 0.6 and a thermal power of 35 kW was used. Microphones attached to the test rig were used to measure the acoustic pressure in the combustion chamber. The acoustic power spectral density is shown in Fig. 15. The measured acoustic spectra show a significant attenuation (>30dB) of the dominant peak at about f=1100 Hz (half-wave resonance of the fluid channels) and its harmonic f=2200 Hz.

LIST OF REFERENCE SIGNS

**[0059]**

| | |
|---|---|
| 1 | engine device |
| 2 | combustor |
| 10 | injector device |
| 11 | fluid channel assembly |
| 111 | fluid channel |
| 1111 | fluid channel wall |
| 1112 | injection hole |
| 1113 | mixing region |
| 112 | detuning cavity |
| 1121 | main cavity |
| 1122 | neck |
| 1123 | funnel-shaped wall |
| 113 | fuel injection hole |
| 12 | base body |
| 13 | mixing section |
| 131 | fuel lance |
| 132 | fuel distribution space |
| 20 | oxidizer collection space |
| 21 | compressor |
| 30 | fuel reservoir |
| 40 | combustion chamber |
| 41 | flames |
| 50 | turbine |

| | |
|---|---|
| F | fuel |
| O | oxidizing agent |
| G | hot gases |
| EG | exhaust gases |
| Z | common flow direction |

## Claims

**1.** An injector device (10) for an engine device (1), the injector device (10) comprising:

a plurality of fluid channel assemblies (11), each fluid channel assembly (11) forming an assembly resonator exhibiting an assembly eigenfrequency $f_a$,
wherein at least two different types of fluid channel assemblies (11) occur among the plurality of fluid channel assemblies (11), the at least two different types of fluid channel assemblies (11) differing from each other with respect to their assembly eigenfrequency $f_a$,
wherein each fluid channel assembly (11) comprises:
a fluid channel (111) for guiding an oxidizing agent (O), a fuel (F), or a mixture comprising an oxidizing agent (O) and a fuel (F), towards a combustion chamber (40) of the engine device (1), the fluid channel (111) forming a channel resonator exhibiting a channel eigenfrequency $f_c$, and
wherein at least one of the fluid channel assemblies (11) comprises:

at least one detuning cavity (112) being fluidically connected to its fluid channel (111), the at least one detuning cavity forming a cavity resonator exhibiting a detuning cavity eigenfrequency $f_d$,
wherein the detuning cavity eigenfrequency $f_d$ differs from the channel eigenfrequency $f_c$ of the fluid channel (111) to which it is connected.

**2.** The injector device (10) of claim 1,
wherein the fluid channels (111) have a uniform cross-section and a uniform channel length.

**3.** The injector device (10) of claim 1 or 2, wherein the difference in assembly eigenfrequency ($f_a$) between the different types of fluid channel assemblies (11) is at least partially caused by the detuning cavities (112) of the different types having different detuning cavity volumes.

**4.** The injector device (10) of any one of the preceding claims, wherein the difference in assembly eigenfrequency $f_a$ between the different types of fluid channel assemblies (11) is at least partially caused by the different types having a different number of detuning cavities (112) being fluidically connected to the respective fluid channel (111).

**5.** The injector device (10) of any one of the preceding claims,

wherein each fluid channel (111) comprises a mixing region (1113) for mixing the oxidizing agent (O) with the fuel (F), and
wherein the at least one detuning cavity is arranged downstream of the mixing region (1113).

**6.** The injector device (10) of claim 5,

wherein each fluid channel is delimited by a channel wall, the channel wall comprising a fuel injection hole (1112) for allowing the fuel (F) to enter the mixing region (1113), and
wherein the fuel injection hole (1112) is arranged

upstream of the at least one detuning cavity (112).

7. The injector device (10) of any one of the preceding claims,
wherein the fluid channels (111) extend in parallel to each other, thereby defining a common flow direction (Z).

8. The injector device (10) of claim 7, wherein each fluid channel (111) is spaced apart from the other fluid channels (111) in a plane perpendicular to the flow direction (Z) by a gap which is at least as large as a cross section of the respective fluid channel (111).

9. The injector device (10) of claim 7 or 8,
wherein at least one detuning cavity (112) is arranged in-between two fluid channels (111).

10. The injector device (10) of any one of the preceding claims,
wherein at least one of the detuning cavities (112) is a quarter-wave resonator with a circular cross section that is preferably smaller than a cross section of the fluid channel (111) to which it is fluidically connected.

11. The injector device (10) of claims 1-9, wherein at least one of the detuning cavities (112) is a Helmholtz-resonator with a main cavity (1121) and a neck (1122) through which the detuning cavity (112) is fluidically connected to the fluid channel (111).

12. The injector device (10) of any one of the preceding claims, wherein the injector device (10) comprises a number N of fluid channel assemblies (11) and wherein a number M of different types of fluid channel assemblies (11) differing from each other with respect to their assembly eigenfrequency ($f_a$) occur among the N fluid channel assemblies (11), the ratio M/N being in the range of 0.5-1.

13. A method of manufacturing an injector device (10) according to any one of the preceding claims, wherein the injector device (10) is manufactured using a 3D-printing process.

14. The method of claim 13, wherein the 3D-printing process comprises selective laser melting of a powder material.

15. An engine device (1) comprising:

an oxidizer collection space (20) for collecting an oxidizing agent (O);
a fuel reservoir (30) for containing a fuel (F),
a combustion chamber (40), and
an injector device (10) according to any one of the preceding claims, wherein the injector device (10) is arranged to fluidically connect the oxidizer collection space (20) and the fuel reservoir (30) to the combustion chamber (40).

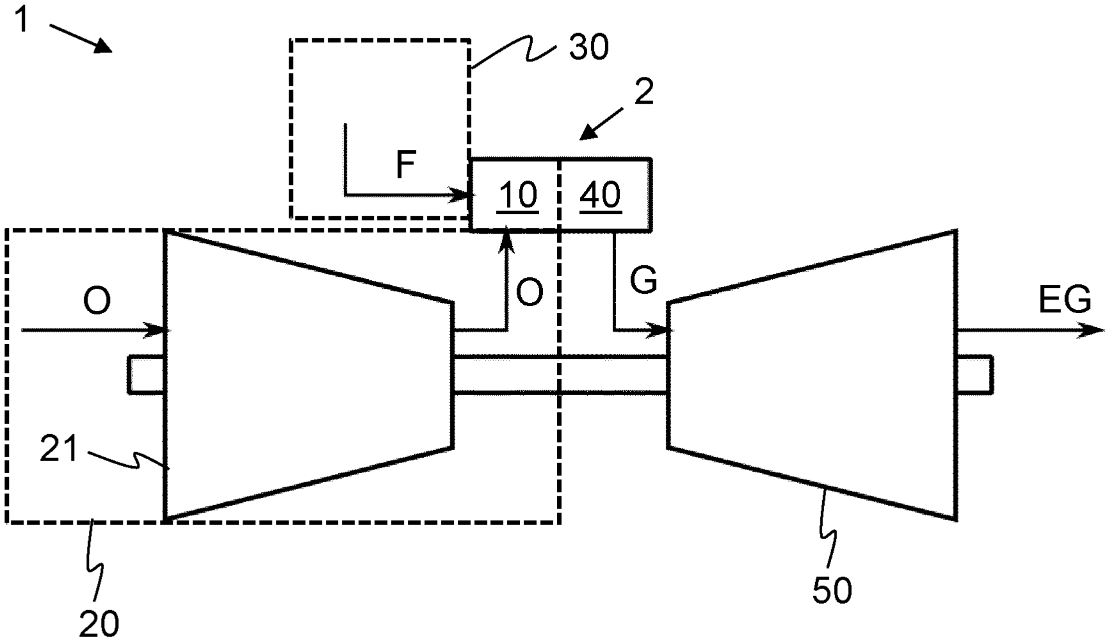



**FIG. 1**

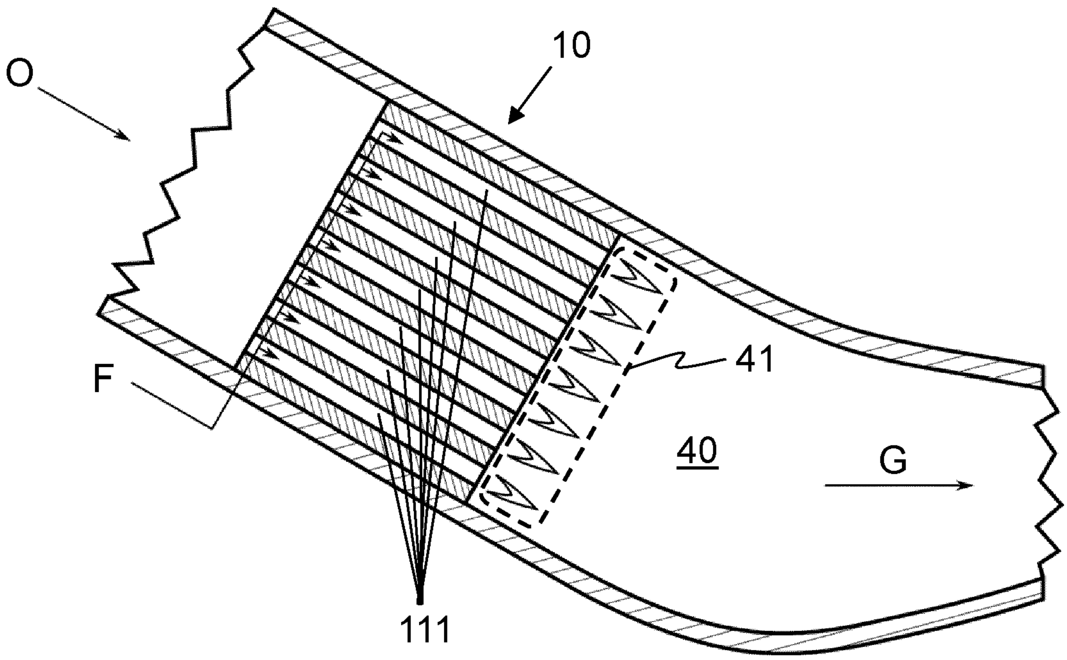



**FIG. 2**
**(prior art)**

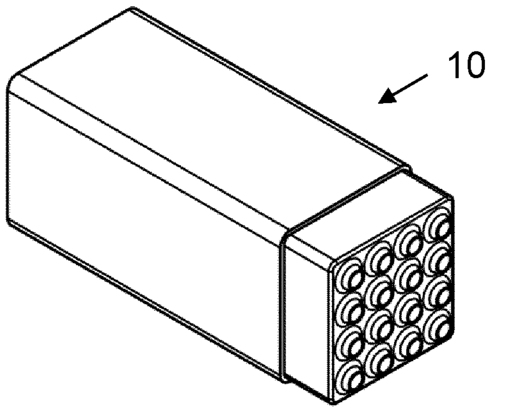



FIG. 3

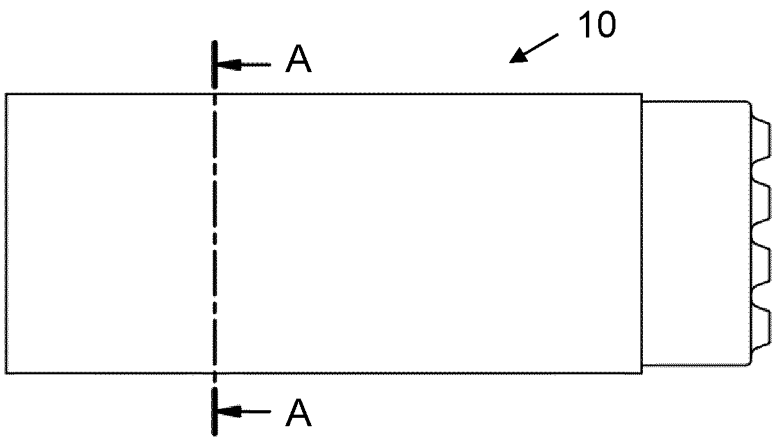



FIG. 4

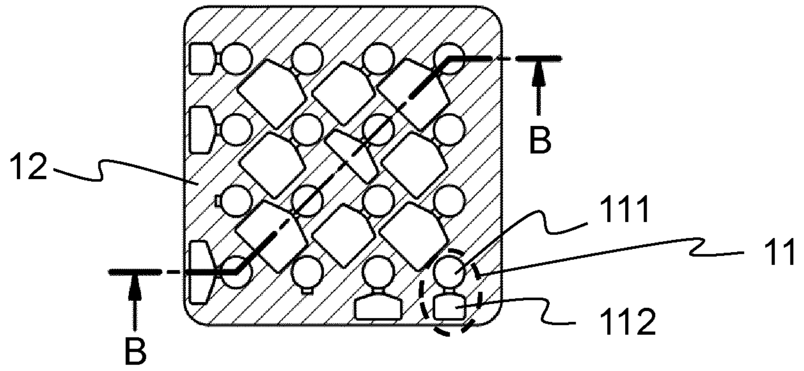



FIG. 5

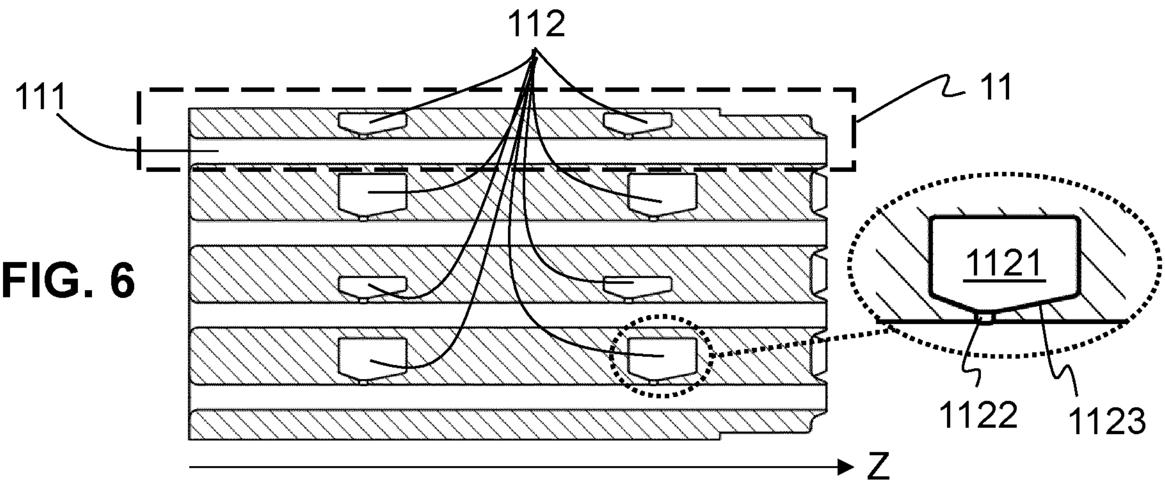



FIG. 6

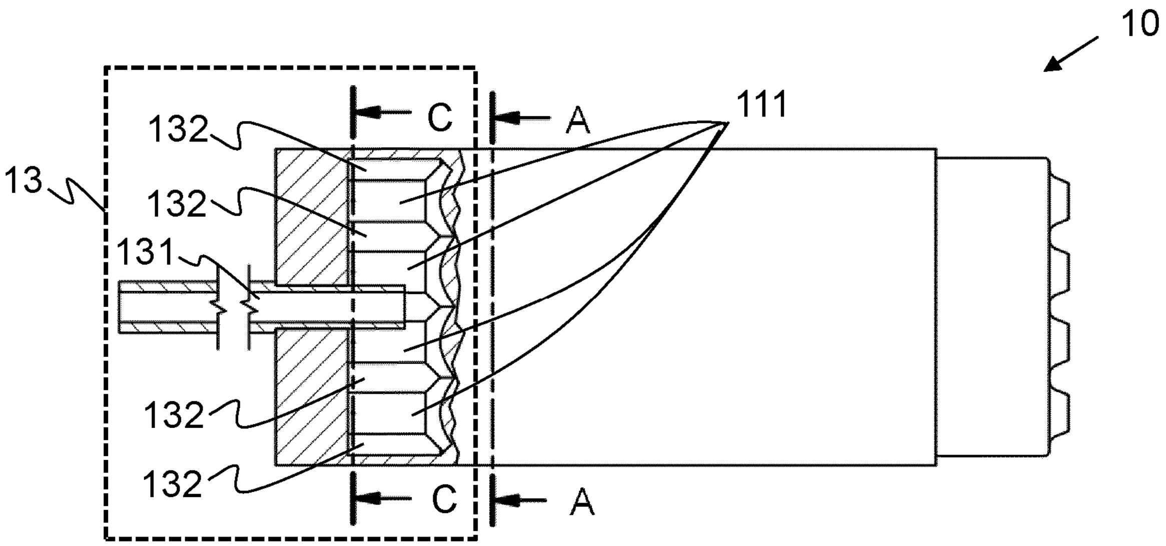



FIG. 7

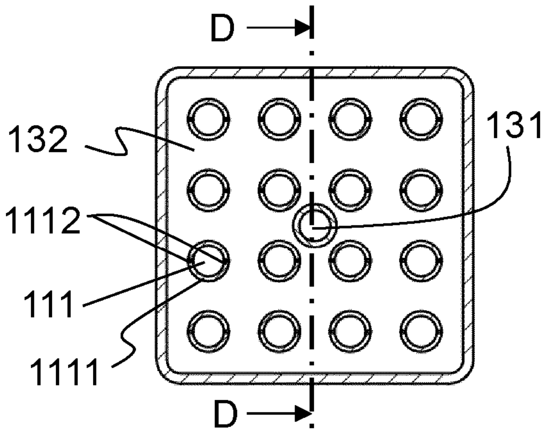



FIG. 8

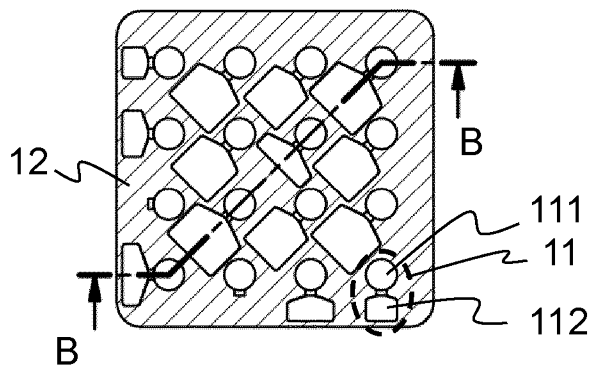



FIG. 9

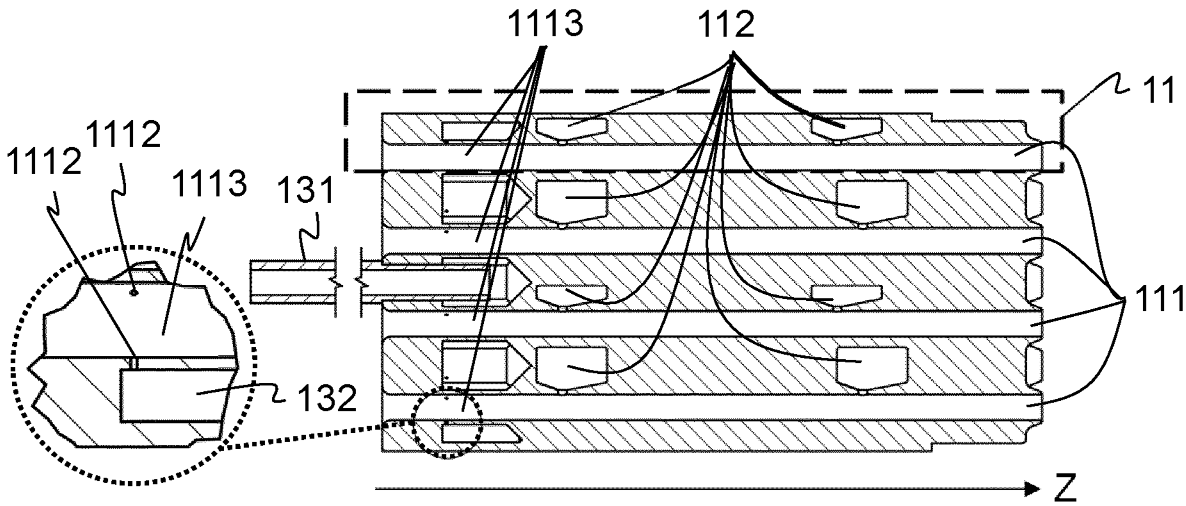
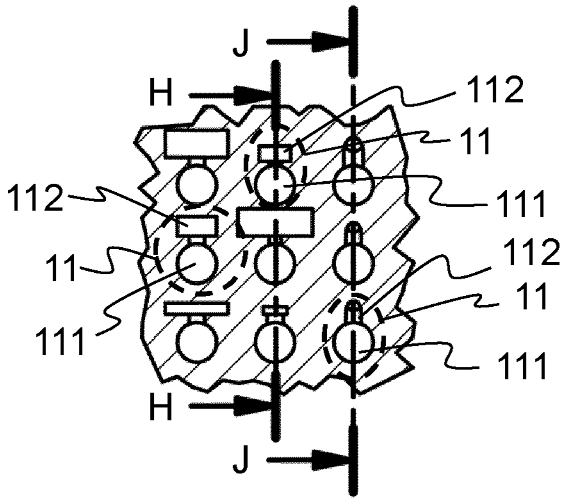



FIG. 10

FIG. 11



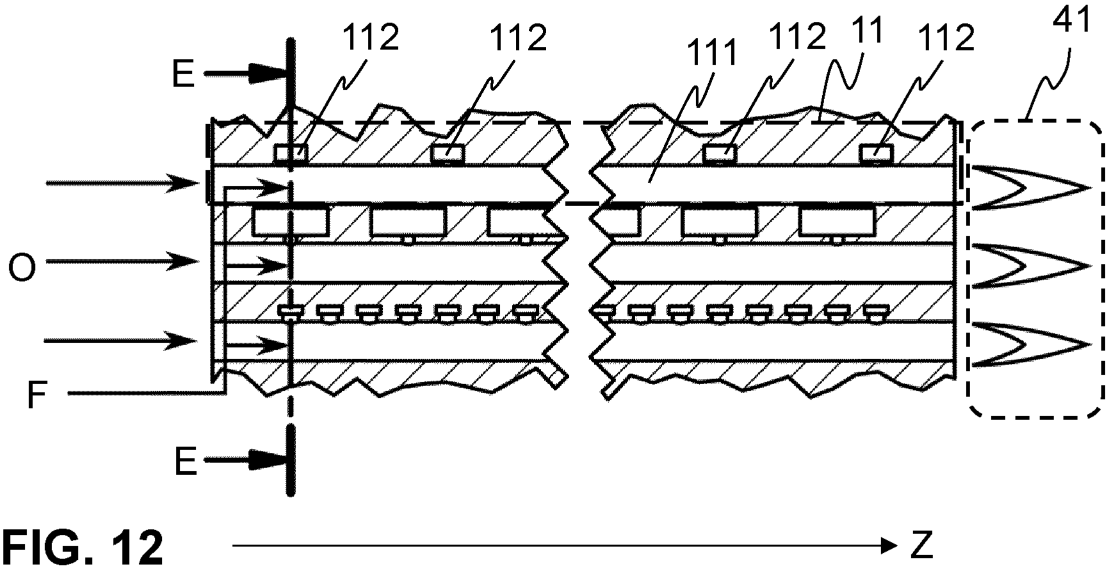




FIG. 12

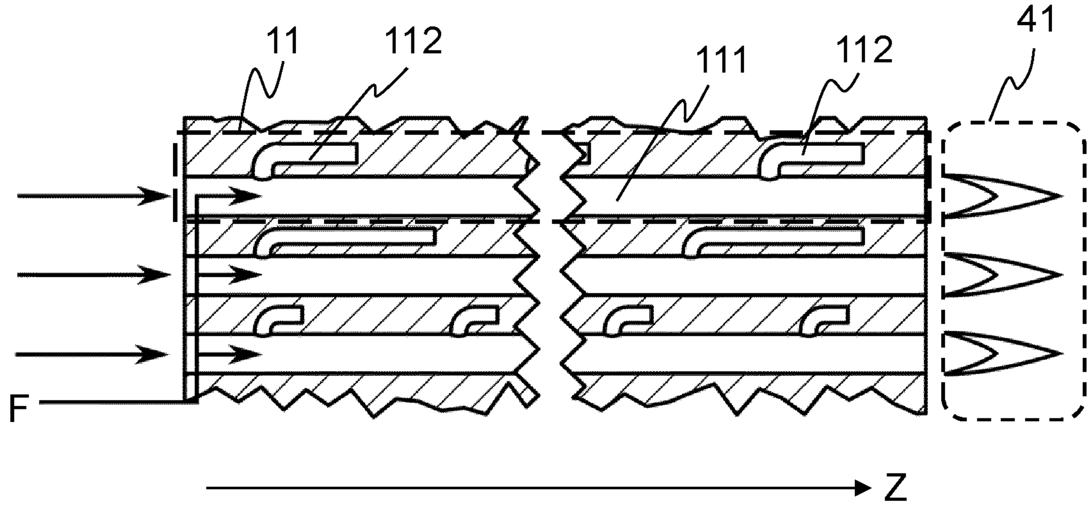



FIG. 13

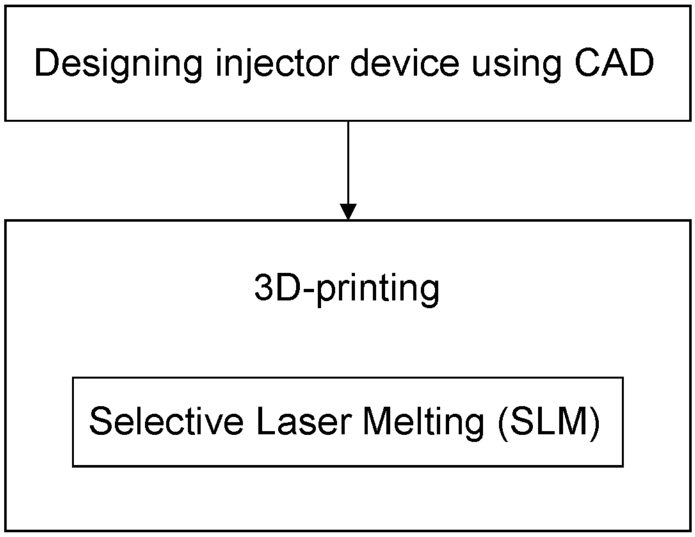

Designing injector device using CAD
3D-printing
Selective Laser Melting (SLM)

FIG. 14

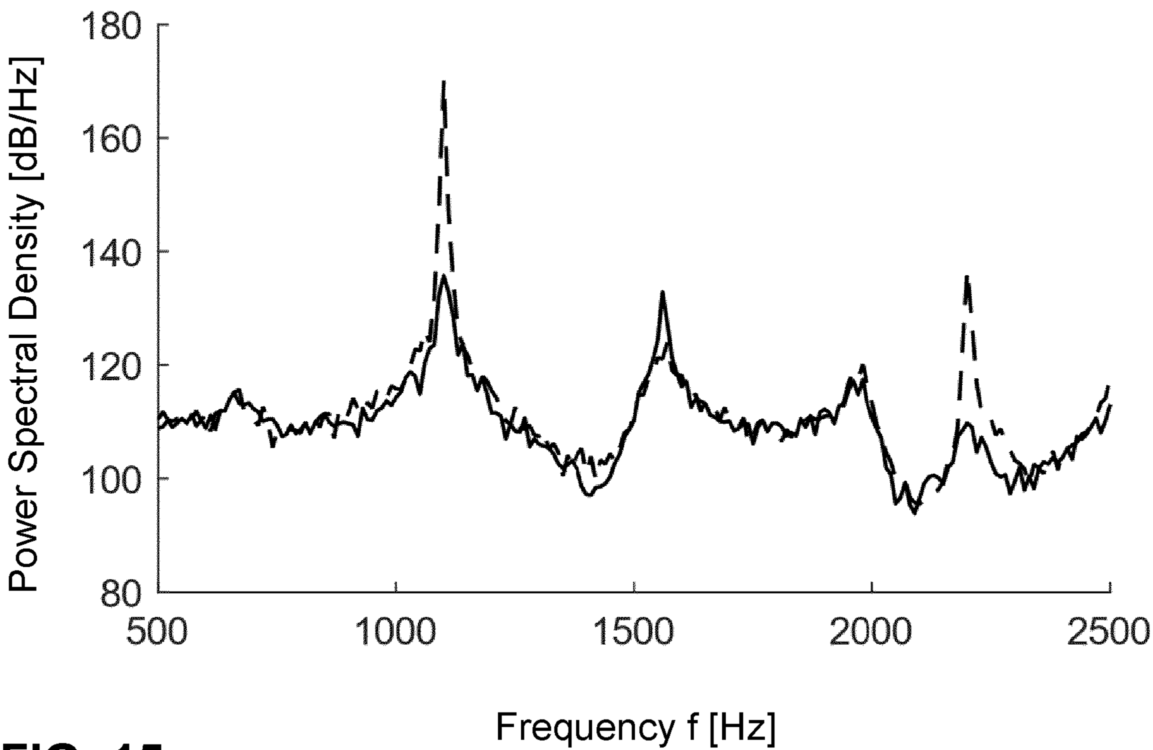

Power Spectral Density [dB/Hz]
180
160
140
120
100
80
500
1000
1500
2000
2500
Frequency f [Hz]

FIG. 15

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Application Number
EP 24 21 1075

## DOCUMENTS CONSIDERED TO BE RELEVANT

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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 19 February 2025 | Mootz, Frank |

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# EUROPEAN SEARCH REPORT

Application Number
EP 24 21 1075

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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 19 February 2025 | Mootz, Frank |

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CATEGORY OF CITED DOCUMENTS

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