Tagungsbericht 34/1997

Topologie

31.8.–6. 9. 1997

The conference was organized by R. Kirby (Berkeley), W. Lück (Münster) and E.G. Rees (Edinburgh). About 50 participants from all over the world attended the meeting.

A special feature was a series of 3 talks of Sylvain Cappell on characteristic classes of singular varieties in the context of intersection homology. The highlight were new applications to Euler-McLaurin formulas.

In addition, there were 16 talks on new developments in many branches of (algebraic) topology. A focus of the talks was low dimensional topology, ranging from the study of certain knot and link invariants in dimensions three and four to a refinement of Seiberg-Witten invariants. Other speakers computed L^2-invariants, higher analytic torsion, algebraic and topological K-theory. One result is the extension of the Atiyah completion theorem to discrete groups. One speaker established the Baum-Connes conjecture for a new large class of groups. We also learned about the mysteries of the signature operator and spaces of holomorphic maps.

Every talk attracted nearly all the participitians. The schedule gave

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plenty of room for discussions. This opportunity was widely used and considered at least as important as the series of talks.

Gratefully acknowledged was the pleasent atmosphere created by the staff of the Institute. It helped to make the meeting as successful as it was.

Abstracts of the talks

Stefan Bauer: On connected sums of four-manifolds

For a fixed *spin*^{c} structure on a simply connected 4-manifold there is a monopole map Ψ defined between affine Banach spaces. The moduli space of zeros of Ψ is used to define Seibert-Witten invariants. The map Ψ is proper and can be extended to a proper map between Banach spheres. The linearisation of Ψ is Fredholm. It can be used to associate to Ψ a stable S^1-equivariant map between finite dimensional spheres

$$[\Psi] \in \pi^{S^1}_{ind}(S^0)$$

Seiberg-Witten theory can be recovered from $[\Psi]$. Moreover, there is a formula for connected sums

$$[\Psi_X] \wedge [\Psi_Y] = [\Psi_{X\#Y}].$$

As a consequence one gets several nonvanishing results for connected sums. For example, in case of a diffeomorphism

$$X\#K3 \equiv Y\#K3$$

the Seiberg-Witten invariants of X and Y satisfy $SW(X) \cong SW(Y) \pmod 2$. Both, the invariant and the connected sum theorem also extend to non-simply connnected manifolds. In this situation, $[\Psi] \in \pi^0_{S^1,U}(Pic^0(X); ind)$ is an element of a twisted equivariant stable cohomotopy group of the Picard group $Pic^0(X) := H^1(X,\mathbb{R})/H^1(X,\mathbb{Z})$.

Ulrich Bunke: Computations with higher analytic torsion

Higher analytic torsion was introduced by Lott. Let G be a connected compact Lie group. By $\tilde{I}(G)$ we denote the space of invariant formal power series on the Lie algebra of G modulo constants. If M is a closed orientable G-manifold, then Lott defined the higher analytic torsion $T(M) \in \tilde{I}(G)$.

Let $U(G)$ denote the Euler ring of G. Then we have the equivariant Euler characteristic $\chi_G(M) \in U(G)$.

Theorem : *There exists a homomorphism $T_G : U(G) \to \tilde{I}(G)$ such that for any closed orientable G-manifold $T(M) = T_G(\chi_G(M))$.*

If H is a closed connected subgroup, then we have restriction maps $res^G_H : U(G) \to U(H)$, $res^G_H : \tilde{I}(G) \to \tilde{I}(H)$. Moreover we have $T_H \circ res^G_H = res^G_H \circ T_G$. We observe that T_G is determined by $\{T_H \mid H \subset G, H \cong S^1\}$. Thus in order to compute T_G it suffices to know T_{S^1}.

Theorem : *Let $H \subset S^1$ be a closed subgroup and $[S^1/H]$ be the corresponding element of $U(G)$. Then*

$$T_{S^1}([S^1/H]) = \begin{cases} 0 & H = S^1 \\ 2\sum_{k=1}^{\infty} \begin{pmatrix} 4k \\ 2k \end{pmatrix} \zeta_R(2k+1) \left(\frac{y|H|}{8\pi}\right)^{2k} & H \neq S^1 \end{cases},$$

where $y \in (s^1)^*$ is normalized such that $y(X) = 1$ and $X \in s^1$ is minimal such that $\exp(X) = 1$.

Using the higher analytic torsion form of Bismut/Lott we gave a construction which associates to a closed manifold M together with an acyclic flat hermitean vector bundle F a class h_T in $H_c^{ev}(\mathrm{Diff}(M)^0, \mathbb{R})$, the continuous group cohomology of $\mathrm{Diff}(M)^0$. If $M = S^1$ and F is one-dimensional with holonomy $\exp(2\pi \imath a)$, then we compute

$$h_T^2 = c\left(\sum_{m=1}^{\infty} \frac{\sin(2\pi m a)}{m^4}\right)\beta \in H_c^2(\mathrm{Diff}(S^1, \mathbb{R}) \ ,$$

where $c \neq 0$ and β is the unique element in $H_c^2(\mathrm{Diff}(S^1)^0, \mathbb{R})$ with $\beta^2 = 0$. Motivated by this example we expect that h_T is in general non-trivial and different from the classes found by Thurston, Haeflinger, Bott.

Sylvain Cappell: Characteristic classes of singular varieties and mapping theorems for them and applications to Euler-McLaurin formulas

We presented various characteristic class theories for singular varieties in both topological and algebraic geometrical settings. These, in the case of divisors, can be related to knot invariants. They can also often be computed by mapping theorems. This is applied to compute invariants of toric varieties, and general Hilbert polynomials of polytopes. Genereral high dimensional versions of Euler-McLaurin formulas with remainder for relating lattice sums to integrals were presented, as developed by U. Shaneson and the speaker.

Ralph L. Cohen: Holomorphic K-theory, Lawson's Chow-Cohomology, and Loop Groups

In this talk I will describe a program to study holomorphic bundles over smooth projective varieties using K-theoretic techniques. The "holomorphic K-theory" I will describe will be defined in terms of spaces of holomorphic mappings from a variety to Grassmannians or to loop groups. I will describe the structure of this theory, how its characteristic classes take values in Lawson's Chow cohomology groups, and how the analogue of Bott periodicity holds for this theory, and is proved using the geometry of loop groups. I will describe results that relate holomorphic K-theory to both algebraic K-theory and topological K-theory, and describe some sample calculations. In doing so I will give a geometric description of the Chern character in terms of the "symmetrized loop group", $\Omega U(n)/\Sigma_n$, where the symmetric group acts on $U(n)$ by conjugation. Finally I will show how this is used to prove a theorem (joint with Lima-Filho) stating that modulo torsion, all Lawson cohomology classes (and in particular all cohomology classes represented by algebraic cocycles) are realized as (algebraic) Chern classes of holomorphic bundles.

Michael Farber: Extended L^2-cohomology and approximation theorems for von Neumann-Betti numbers

The talk discusses generalizations of a theorem of W. Lück (1994), conjectured by M. Gromov, about approximation of von Neumann type topological invariants by finite dimensional ones, constructed by means of a tower of coverings. The generalized version assumes that we have a sequence of unitary flat bundles over X, such that their normalized characters converge to the character of a unitary representation in a finite von Neumann category with a normal trace. We show that the difference between the von Neumann dimension of the homology with coefficients in the infinite dimensional representation and the limit of the normalized Betti numbers of the flat bundles can be understood as torsion dimension of the torsion part of the extended cohomology. Under certain conditions (expressed by means of algebraic number theory) this torsion dimension vanishes and we obtain theorems generalizing the theorem of Lück in several directions.

V. Goryunov: A Bennequin number estimate for transverse knots

It is shown that the Bennequin number of a transverse knot in the standard contact 3-space or solid torus is bounded by the negative of the lowest degree of the framing variable in its HOMFLY polynomial. For $\mathbb{R}^3$, this fact was established earlier by Fuchs and Tabachnikov (1995) by comparison of the results of Bennequin and Franks-Williams and Morton. We develop a different, direct approach based on the lowering of the polynomial to transversally framed regular planar curves.

Ursula Gritsch: Morse theory for the Yang-Mills functional via equivariant homotopy theory

In this talk we prove the existence of non minimal critical points of the Yang-Mills functional over certain 4-manifolds M_{2g} for $g = 0, 2, 3, \ldots$ for a generic invariant metric. The proof uses Morse theory for the Yang-Mills functional and a homotopy theoretic calculation.

The manifolds M_{2g} are obtained by taking the quotient by an orientation preserving involution of the product of a Riemann surface with even genus and the two sphere. These manifolds are spin and are acted on by the Lie group $SU(2)$ by the trivial action on the Riemann surface factor and by the standard action on the S^2-factor. We treat the Yang-Mills functional on the space of invariant connections on the spinor bundles modulo the action by the invariant gauge group as a Morse function.

We show that for $g = 0$ the negative spinor bundle Δ^- over the manifold M_0 admits at least one Yang-Mills connection which is not anti self dual and for $g \geq 2$ the positive spinor bundle Δ^+ over the manifold M_{2g} admits at least $2g + 1$ Yang-Mills connections one of which is not anti self dual.

Jacques Hurtubise: Holomorphic maps of surfaces

Morse theory fails for the energy functional on the space $\Omega^2(X)$ of smooth based maps from the sphere to a manifold X. The same holds when one replaces the sphere by an arbitrary surface Σ. The critical points of the functional are harmonic maps; the minima, when X is Kahler and there are holomorphic maps in the homotopy class, are holomorphic.

One can however prove a statement which is "asymptotically Morse theoretic". Namely, one considers the inclusions

$$Hol_k(S^2, X) \to \Omega^2(X)$$

where k is a degree, and shows that there is a linear function $l(k)$ going to infinity with k such that the inclusion induces isomorphisms in homotopy groups π_i for $i < l(k)$. We give a proof for varieties acted on by a solvable linear algebraic group, with a dense free orbit. Examples include flag manifolds, toric varieties, certain spherical varieties, as well as equivariant blowings-up of these. We conjecture that the result holds for rationally connected varieties. (Joint work with C. Boyer and R.J. Milgram)

Michael Joachim: A new model for topological KO-theory and the twisted Atiyah orientation

A smooth closed manifold has a KO-fundamental class if and only if its first and its second Stiefel-Whitney class is zero. This fact corresponds to the existence of an orientation $D : MSpin \to ko$, the Atiyah orientation. We show how a parametrized version of the Atiyah orientation can be obtained as a Borel construction on $D : MSpin \to ko$ using a group $G \simeq K(\mathbb{Z}/2, 0) \times$

$K(\mathbb{Z}/2,1)$ acting on specific models for $MSpin$ and ko. This 'twisted Atiyah orientation' leads to a transformation from a twisted $MSpin$-bordism theory to a twisted connective KO-theory. We use the transformation to associate to any closed manifold M whose universal cover is spin an invariant in a twisted ko-homology group $ko_*(B\pi;\zeta)$, where $\pi = \pi_1(M)$ is the fundamental group and the 'twisting data' ζ is a map $\zeta : B\pi \to BG \simeq K(\mathbb{Z}/2,1) \times K(\mathbb{Z}/2,2)$, that is determined by $w_1(M)$ and $w_2(M)$ up to homotopy. We expect that a manifold M as above with $dim(M) \geq 5$ has a metric with positive scalar curvature if and only if the invariant lies in a canonically defined subgroup $ko_*^+(B\pi;\zeta) \subset ko_*(B\pi;\zeta)$. This generalizes a result of Stephan Stolz who proved the statement for spin manifolds.

Thang Le: Finite type invariants of integral homology 3-spheres

We briefly review the theory of finite type invariants (Vassiliev invariants) of knots and then describe the theory of finite type invariants of integral homology 3-spheres.

Let $\mathcal{M}$ be the vector space over the rationals freely generated by integral homology 3-spheres. For a framed link L in an integral homology 3-sphere M let

$$[M,L] = \sum_{L' \subset L} (-1)^{|L'|} M_{L'},$$

where the sum is taken over all sublinks of L, $M_{L'}$ is the 3-manifold obtained from M by surgery along L', and $|L'|$ is the number of components of L'. We assume that the linking number of any two components of L is 0, and that the framing of any component is $+1$ or -1. Then $[M,L]$ is an element of $\mathcal{M}$. Let $\mathcal{F}_n$ be the subspace of $\mathcal{M}$ generated by all such $[M,L]$, where L has n components.

In analogy with the knot case, Ohtsuki introduced the following definition. An invariant I of integral homology 3-spheres with values in a vector space is said to be of order $\leq n$ if the restriction of I to $\mathcal{F}_{n+1}$ is 0.

Using the Kontsevich integral of framed links and the Kirby calculus, we constructed an invariant Ω of closed oriented 3-manifolds (this is a joint work with Murakami and Ohtsuki). The invariant takes values in a graded algebra of trivalent graphs. It turns out that Ω is a universal invariant for finite type invariants: its degree n part is an invariant of degree $3n$ which dominates all other invariants of the same order. (There is no finite invariants of order not a multiple of 3). So this invariant should play the role of the Kontsevich integral for integral homology 3-spheres. We exhibit the relation between Ω

and quantum invariants of 3-manifolds at roots of unity and discuss some applications.

Bob Oliver: The completion theorem in K-theory for proper actions of infinite discrete groups

In this talk, I described joint work with Wolfgang Lück about proper actions of infinite discrete groups. The main results are the following two theorems.
Theorem 1 Let G be any discrete group. Then $K_G^*(-)$, defined using G-vector bundles, is a cohomology theory (satisfying Bott periodicity) on the category of finite proper G-CW pairs.
Theorem 2 Let G be a discrete group such that the universal proper G-CW complex, $E_{\mathcal{FIN}}(G)$, has the homotopy type of a finite G-CW complex. Set $I = IK_G(E_{\mathcal{FIN}}(G))$. Then for any finite proper G-CW complex X, $K^*(EG\times_G X) \cong K_G^*(X)\hat{}_I$ (the completion with respect to the ideal generated by I).

Theorem 2 can be stated in a form which holds for any discrete group G. Both theorems are false, in general, for positive dimensional noncompact Lie groups.

Erik Pedersen: Assembly maps and the Baum Connes conjecture

Parts of the talk represent joint work with John Roe.

We prove that the assembly map as defined by Davis and Lück agrees with the Baum Connes map in the case of topological K-theory. We also give an easy proof that if $E\Gamma$, the classifying space for proper Γ actions satisfies that $E\Gamma^H$ is Lipschitz contractible for all finite subgroups H of Γ, then the Baum Connes map is a split monomorphism of spectra. Examples of Lipschitz contractible spaces are given by just about any non positive curvature condition.

John Rognes: Two-primary algebraic K-theory of rings of integers in number fields

The lecture represents joint work with C. Weibel. As an application of V. Voevodsky's proof of the Milnor conjecture we compute the two-primary algebraic K-theory of the ring of integers in any number field, in terms of its étale cohomology groups. In particular we compute the two-primary algebraic K-theory of the integers Z. The answer is roughly 2-periodic for totally imaginary number fields, and roughly 8-periodic for real number fields.

As consequences, we obtain (a) the two-primary part of the Quillen conjecture that there exists a spectral sequence from the étale cohomology of any ring of 2-integers to its K-theory, with finite coefficients, and (b) the two-primary part of the Lichtenbaum conjecture that relates a ratio of orders of algebraic K-groups to a ratio of orders of étale cohomology groups, for totally real number fields. The ratios agree up to the factor 2^{r_1}, where r_1 is the number of real embeddings of the field. By a theorem of A. Wiles, and further work by M. Kolster, one also obtains for totally real Abelian number fields (c) the two-primary part of the Lichtenbaum conjecture that relates the latter ratio above to the value of a zeta-function.

This work fills gaps in related work by C. Weibel, and by B. Kahn. We show how to introduce coefficients in the Bloch–Lichtenbaum spectral sequence from S. Bloch's higher Chow groups to algebraic K-theory. Then work of A. Suslin and V. Voevodsky provide a spectral sequence from the étale cohomology of any number field F to its K-theory, with mod 2^ν or mod 2^∞ coefficients,

There can only be differentials in the mod 2^∞ spectral sequence when F is real, i.e., admits real embeddings. We determine the E_∞ term of the spectral sequence by a comparison with the corresponding spectral sequence for the field of real numbers. It is not known whether the latter spectral sequence admits a product structure, contrary to previous assumptions, so we bypass this question by an additive argument making use of J. Rognes' prior calculation of $K(Q_2)$ by means of topological cyclic homology, i.e., $TC(Z)$. This determines the mod 2^∞ algebraic K-theory of the number field, from which the two-primary K-theory of the ring of integers is deduced by the localization sequence and universal coefficient sequence.

Jonathan Rosenberg: Secrets of the De Rham and Signature Operators

Suppose M is a closed manifold. Via Kasparov's KK-theory, an elliptic operator D on M (usually anticommuting with a $\mathbf{Z}/2$-grading on the underlying vector bundle) defines a K-homology class $[D]$ on M. This class has the property that the index of D with coefficients in a vector bundle E is $\langle [D], [E] \rangle$, computed via the dual pairing between K-homology and K-cohomology. In this talk, we address the problem of determining what topological information about M is contained in $[D]$ when D is the Euler characteristic operator or signature operator. These two naturally arising operators come from the de Rham operator $d + d^*$ with two different gradings: the grading by parity of degreee in the case of the Euler characteristic operator, and a grading coming from the Hodge $*$-operator in the case of the signature operator. (The signature operator is only defined when M is oriented.)

It turns out that when D is the Euler characteristic operator, $[D]$ is "trivial": it is just the image of $\chi(M) \in \mathbf{Z} \cong KO_0(\mathrm{pt})$ in $KO_0(M)$. But in the case of the signature operator, $[D]$ is a very rich object. Localized away from 2, it is basically Ranicki's orientation class for $\mathbf{L}^\bullet$ homology. Localized *at* 2, it is a more mysterious homeomorphism and cobordism invariant, which is *not* a homotopy invariant. The "signature operator at 2" comes from certain natural transformations $\sigma_n : (H_n)_{(2)} \to (K_n)_{(2)}$ which unfortunately do *not* fit together into a natural transformation of homology theories. This latter information is joint work with Shmuel Weinberger.

Thomas Schick: L^2-torsion of hyperbolic manifolds

L^2-Reidemeister torsion is a secondary invariant defined for L^2-acyclic CW-complexes which fulfill an additional technical condition (conjectured to be true always). It has many properties similar to the Euler characteristic, such as (simple) homotopy invariance, gluing- and fibration formulae, multiplicity under coverings. Using its analytic version (equal to the topological one by a deep theorem of Burghelea et al.), we prove

Theorem: Given a hyperbolic manifold M^m of finite volume, m odd, then

$$T^{(2)}(M) = C_m \operatorname{vol}(M)$$

The constant C_m depends only on the dimension and is explicitely known in dimensions $3, 5, 7$. The statement was extended from the closed case (due to Lott) to the case $\partial M \neq \emptyset$ by Lück and the speaker.

For an irreducible 3-manifold M with $|\pi_1| = \infty$ and with boundary consisting of incompressible tori, with a JSJT-splitting into hyperbolic pieces $M_1, \dots, M_h$ and Seifert pieces $M_{h+1}, \dots, M_n$ this concludes the computation of its L^2-torsion as follows:

$$T^{(2)}(M) = -\frac{1}{3\pi} \sum_{i=1}^{h} \operatorname{vol}(M_i)$$

Peter Teichner: Pulling 2-spheres apart in 4-space

We show that two disjoint 2-spheres in $\mathbb{R}^4$ can be pulled apart by a *link homotopy*, i.e. a motion in which the 2-spheres stay disjoint but are allowed to self-intersect. In fact, we prove that the same result is true if only one of the 2-spheres is embedded to begin with. As a corollary, we give a new upper bound on the group of link homotopy classes of link maps $S^2 \amalg S^2 \to \mathbb{R}^4$ in terms of concordance classes of certain classical 2-component links in $\mathbb{R}^3$.

Tomotada Ohtsuki: The perturbative $SO(3)$ invariant of homology circles

TQFT (topological quantum field theory) is defined by axioms, which are satisfied by quantum invariants of 3-cobordisms up to "framing anomaly". To resolve the anomaly, we construct a central extension $\widetilde{SL(2;\mathbb{Z})}$ of $SL(2;\mathbb{Z})$. We also see the relation between the quantum $SO(3)$ invariant and the perturbative $SO(3)$ invariant of links and 3-manifolds, and give the action of $\widetilde{SL(2;\mathbb{Z})}$ on the perturbative $SO(3)$ invariant of homology circles, which, I expect, will be a part of TQFT for the perturbative $SO(3)$ invariant.

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